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NNSS Soils Monitoring: Plutonium Valley (CAU 366) FY2015

prepared by

George Nikolich, Steve Mizell,
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submitted to

Nevada Field Office
National Nuclear Security Administration
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Las Vegas, Nevada

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EXECUTIVE SUMMARY

Desert Research Institute (DRI) is conducting a field assessment of the potential for contaminated soil transport from the Plutonium Valley Contamination Area (CA) as a result of wind transport and storm runoff in support of National Nuclear Security Administration (NNSA) efforts to complete regulatory closure of the contamination areas. The DRI work is intended to confirm the likely mechanism(s) of transport and determine the meteorological conditions that might cause movement of contaminated soils. The emphasis of the work is on collecting sediment transported by channelized storm runoff at the Plutonium Valley investigation sites. These data will inform closure plans that are being developed, which will facilitate the appropriate closure design and post-closure monitoring.

In 2011, DRI installed two meteorological monitoring stations south (station #1) and north (station #2) of the Plutonium Valley CA and a runoff sediment sampling station within the CA. Temperature, wind speed, wind direction, relative humidity, precipitation, solar radiation, barometric pressure, soil temperature, and airborne particulate concentration are collected at both meteorological stations. The maximum, minimum, and average or total (as appropriate) for each of these parameters are recorded for each 10-minute interval. The sediment sampling station includes an automatically activated ISCO sampling pump with collection bottles for suspended sediment, which is activated when sufficient flow is present in the channel, and passive traps for bedload material that is transported down the channel during runoff events. This report presents data collected from these stations during fiscal year (FY) 2015.

The warmest month was August and the coldest month was December. Solar radiation was highest in June and lowest in December and January. Monthly mean wind speeds were highest in the spring (April and May). Winds were generally from the south and southeast throughout the year. Monthly average relative humidity ranged from the teens to greater than 65 percent. During rain storms, the relative humidity approached 100 percent. Monthly total precipitation ranged from zero to approximately 0.84 inch (21.3 millimeters). The month with the highest precipitation total was December. Total precipitation each year was approximately three inches (76 millimeters). However, the northern station received less than the southern station.

Light breezes of 0 mph to 5 mph occurred most frequently (approximately 60 percent of the time at both the northern and southern monitoring stations). The frequency of occurrence diminished approximately exponentially as the wind speed increased such that winds in the 20 mph to 30 mph range occurred less than one percent of the time. Additionally, winds in excess of 15 mph were almost exclusively from the southerly direction. This situation is most likely explained by the topography of the valley because the mountains that define the east and west sides of the valley converge toward the north and protect the northern monitoring station from northerly winds.

Generally, the concentrations of $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 micrometers [μm]) and PM_{10} (particulate matter with an aerodynamic diameter of less than 10 μm) material in the air increased approximately exponentially as wind speed increased. Significant increases in wind-blown dust concentrations were observed when wind speeds exceeded 15 mph. The elevated dust concentrations were almost exclusively associated with winds from the south.

The ratio of PM_{10} to $PM_{2.5}$ is a qualitative indicator of the type of aerosol material that is being measured. The PM_{10} to $PM_{2.5}$ ratio remained below 6 for wind speeds below approximately 15 mph and the ratio increased to approximately 10 as the wind speed increased from 15 mph to 30 mph. This increase in the ratio is an indicator of some suspension and transport of locally derived dust and soil. The ratio increased close to areas of course particles because on average PM_{10} has bigger particles, and therefore a shorter lifetime in the atmosphere than $PM_{2.5}$. However, this ratio cannot be used quantitatively because it is subject to change with changing soil conditions.

The ISCO sampler is turned on to collect samples when a sufficient water depth is detected in the channel. A pressure transducer is used to determine the water depth present, a photoacoustic sensor is used to determine the distance from the sensor to the dry channel bed or water surface, and a wetness plate is used to report the presence of water as a result of changes in electrical resistivity on the plate. Multiple sensors are used because each is subject to erroneous output: the transducer may dry out and fail or be slow to respond, the photoacoustic sensor may respond to windblown objects, and the wetness plate may respond to humid conditions or soil moisture condensation. To minimize the potential for false reports of water in the channel, the ISCO sampler is programed to turn on only if all three sensors reported the presence of sufficient water in six successive observations made 10 seconds apart. Water was detected by the sensor array but the measured depth of water was not sufficient to turn on the ISCO sampler and collect a sample. Additionally, no bedload samples were collected during FY2015.

A review of the data collected during FY2015, and presented here, led to the following principal observations and conclusions:

1) A pressure transducer, a wetness sensor, and a photoacoustic sensor are used to detect water in the ephemeral channel and cause the ISCO to turn on for sample collection. Although water was detected within the channel, it was not deep enough to turn on the ISCO sampler; therefore, no runoff water samples were collected for suspended sediment analysis during FY2015.
2) The ratio of PM_{10} to $PM_{2.5}$ dust concentrations observed at the Plutonium Valley monitoring stations indicate suspension and transport of some locally derived dust and soil.
3) Airborne dust concentrations increase with increasing wind speed. They began to become significant as wind speeds exceed 15 to 20 mph. The supply of dust particles available for resuspension at any time is limited, therefore, airborne dust concentrations began to decline shortly after the winds pick up.
4) During FY2015, winds in excess of 15 mph were recorded less than four percent of the year (equivalent to approximately 350 hours). However, the dust generating wind events are generally short-lived; they seldom last more than a few hours.
5) In general, the strongest winds and the highest dust concentrations are associated with winds blowing from the north.

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LIST OF ACRONYMS

Am-241	Americium-241
CA	Contamination Area
CAS	Corrective Action Site
CAU	Corrective Action Unit
DOE	Department of Energy
DRI	Desert Research Institute
EPA	Environmental Protection Agency
FY	fiscal year
GOES	Geostationary Operational Environmental Satellite
NFO	Nevada Field Office
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
PM	particulate matter
$PM_{2.5}$	particulate matter with aerodynamic diameter less than 2.5 micrometers
PM_{10}	particulate matter with aerodynamic diameter less than 10 micrometers
TDR	time domain reflectometry
WRCC	Western Regional Climate Center

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INTRODUCTION

The U.S. Department of Energy (DOE) National Nuclear Security Administration (NNSA), Nevada Field Office (NFO), Environmental Restoration Soils Activity has authorized Desert Research Institute (DRI) to conduct field assessments of the potential transport of radionuclide-contaminated soil from Corrective Action Unit (CAU) 366, Area 11 of the Plutonium Valley Dispersion Sites Contamination Area (CA) during precipitation runoff events, as well as to monitor wind suspension of fine soil particles.

Aerial surveys in selected portions of the Nevada National Security Site (NNSS) suggest that radionuclide-contaminated soils may be migrating along ephemeral channels in Areas 3, 8, 11, 18, and 25 (Colton, 1999). In Area 11, several low-level airborne surveys of the Plutonium Valley Dispersion Sites (CAU 366) show plumes of americium-241 (Am-241) that extend along ephemeral channels (Colton, 1999). These plumes are shown in Figure 1, where marker 5 shows a plume that extends below Corrective Action Site (CAS) 11-23-04 (marker 4) and marker 6 shows a plume that extends below CAS 11-23-03 (marker 3).

Plutonium Valley, located in Area 11 of the NNSS, was selected for the study because aerial survey evidence suggests downstream transport of radionuclide-contaminated soil. The aerial survey (Figure 1) shows a well-defined finger of elevated radioactivity (marker 5) that extends to the southwest from the southernmost detonation site (marker 4). This finger of contamination overlies a drainage channel mapped on the topographic base map that is used to present the survey data, which suggests that surface runoff is a likely cause of the down-channel extension of the contaminated area. Additionally, installing monitoring instruments at sites that are strongly suspected of conveying soil from areas of surface contamination provides the most efficient means of confirming that surface runoff may transport radioactive contamination during precipitation/runoff events.

Closure plans being developed for the CAUs on the NNSS may include post-closure monitoring for the possible release of radioactive contaminants. Determining the potential transport of radionuclide-contaminated soils under ambient meteorological conditions will facilitate an appropriate closure design and post-closure monitoring program.

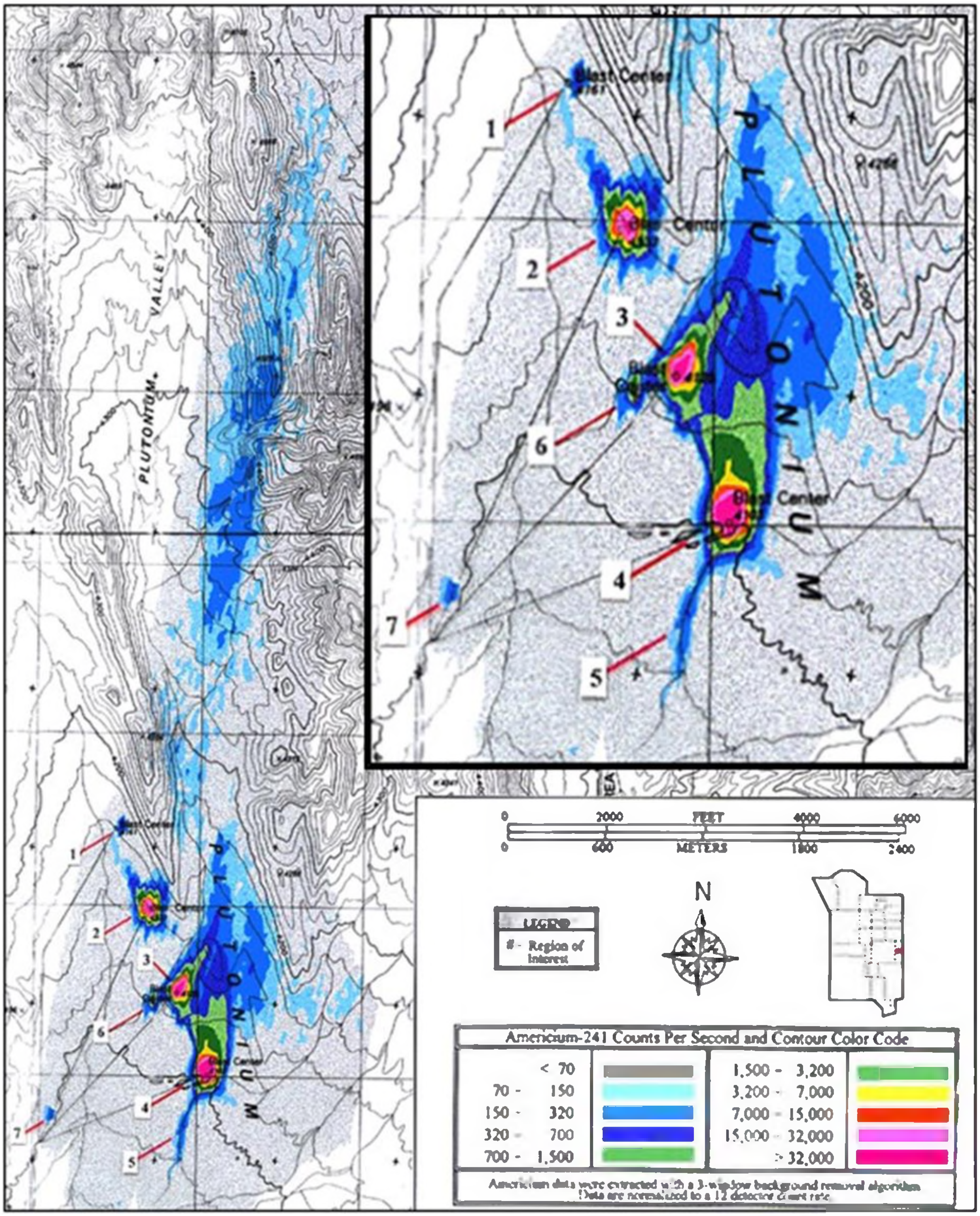

Figure 1. Americium-241 detections in Plutonium Valley suggest migration of radionuclide-contaminated soils along channels that convey runoff away from the Corrective Action Sites. The inset focuses on the ground zero areas. Markers 1 through 4 identify the four Project 56 ground zero sites, items 5 and 6 identify plumes in channels draining the ground zero areas, and item 7 designates an isolated low-activity spot (from Colton [1999], Figure 5).

BACKGROUND

Plutonium Valley is located east of Yucca Flat Dry Lake in Area 11 of the NNSS in southeastern Nye County, Nevada. The valley is approximately 7.5 miles (12.07 km) long and 2.25 miles (3.62 km) wide. The highest point on the drainage divide is French Peak 5,238 ft (1,596.54 m) at the south end of the valley; the lowest point, 4,030 ft (1,228.34 m), is at the outlet to Yucca Flat. Yucca Flat dry lake is approximately 2 miles (3.22 km) west of the outlet.

Project 56, which consisted of a series of four nuclear device safety tests, was conducted in the valley in 1955 and 1956. The safety tests were performed at test beds 11a through 11d (Figure 1, markers 1 through 4), which are aligned north to south in the valley. These test beds have been designated CASs 11-23-01, 11-23-02, 11-23-03, and 11-23-04, respectively, within CAU 366. Additionally, two contaminated waste disposal sites, CAS 11-08-01 and 11-08-02, are also included within CAU 366. The test conducted at test bed 11d (Figure 1, marker 4) (CAS 11-23-04), the southernmost test bed, resulted in extensive alpha contamination on the ground surface (B. Bailey, written communication, October 12, 2010) surrounding ground zero. Aerial surveys (Colton, 1999) detected high concentrations of Am-241 around the three southern test beds (Figure 1, markers 2 through 4) and a significant plume of Am-241 distributed in a north-northeast direction from the southernmost two test locations (Figure 1, markers 3 and 4). The Am-241 plume extending to the north-northeast from the test beds along the west face of the hills that define the eastern boundary of Plutonium Valley is reported by Colton (1999) to have relatively low radioactivity levels (up to 700 counts per second, Figure 1). This plume is believed to have resulted from air dispersal during the test events. It is disconnected from and uphill of the test beds and is not considered a priority issue with respect to potential transport of contaminants by runoff. These surveys also showed Am-241 concentrations above background in a channel that conveys runoff toward the south from the southernmost test bed, CAS 11-23-04 (Figure 1, marker 5). This channel turns westward and when runoff is sufficient, it carries water out of the valley toward Yucca Flat Dry Lake. Because this channel conveys runoff that has traversed the southernmost test bed, which is reported to have up to 32,000 counts per second americium (Colton, 1999), there is potential for runoff to transport significant levels of contamination with the sediment eroded from the test bed.

RESEARCH APPROACH

The presence of radionuclide-contaminated soils in a channel that traverses the southernmost CAS in the Plutonium Valley CA suggests radionuclide-contaminated soil has been transported during runoff events that have occurred in the past. Previous studies (Colton, 1999; Shinn *et al.*, 1993) also suggest that surface water has transported radionuclide-contaminated soils in the past, which suggests that additional surface movement of contaminated soils is possible in the future.

Desert Research Institute proposed a field-scale assessment of the meteorological and hydrologic conditions that would potentially lead to the transport of radionuclide-contaminated soil from the Plutonium Valley CA. The research plan included measuring local meteorological parameters and collecting suspended and bedload sediment transported during runoff events. The precipitation and runoff data will be used to establish the threshold conditions that would likely lead to the transport of soil particles, including radionuclide-contaminated soils. Such thresholds will aid in establishing the conditions that would require monitoring drainage channel transport pathways to be implemented under a future closure plan.

Two meteorological stations, instrumented to measure temperature, relative humidity, wind speed, wind direction, soil volumetric water content, soil temperature, solar radiation, barometric pressure, precipitation, and wind-borne particulate matter, were installed in uncontaminated areas north and south of the Plutonium Valley CA on August 24 and 25, 2011. Figure 2 shows the locations of the instrument stations relative to the ground zero sites in Plutonium Valley and Figure 3 shows photographs of the two meteorological stations. Location coordinates for the two meteorological stations are provided in Table 1. The meteorological stations were installed to determine variations in climatic conditions and predominant seasonal wind directions. In these installations, soil water content values are inferred from time domain reflectometry (TDR) observations. However, the TDR instruments were not calibrated to the specific soil conditions at each station, and therefore the moisture content values are relative rather than absolute. The southern meteorological station (station #1) includes Geostationary Operational Environmental Satellite (GOES) data transmission equipment that is used to transmit hourly summaries of accumulated meteorological data to the Western Regional Climate Center (WRCC) at the DRI offices in Reno once each day. At the WRCC, the data are uploaded to a restricted access internet webpage that is available to the project personnel.

An ISCO sampler was installed within the Plutonium Valley CA (Figures 2 and 4) to collect suspended sediment samples during a significant runoff event. Additionally, two bedload traps were installed near the ISCO sampler to collect samples of bedload sediment during runoff events. The coordinates of the ISCO sampler are given in Table 1. This location is approximately 0.4 miles (0.64 kilometers) downstream of the southernmost test ground zero (CAS 11-08-04) and approximately 0.6 miles (0.96 kilometers) upstream of the detention basin at the southwest corner of the CA. The ISCO installation includes a photoacoustic distance sensor to detect the presence of water in the channel and report the distance to the dry channel bed or water surface, a wetness sensor to indicate the presence of moisture, and a pressure transducer to estimate the water depth in the channel. Water depth in the channel is considered adequate for sampling when the photoacoustic sensor reports the reflecting surface is approximately 4.2 inches (106.68 mm) above the dry channel bed, the pressure transducer reports the depth of water is 4 inches, and resistance of the wetness plate drops to 100 ohms (Appendix C). All three sensors must indicate sufficient water before the ISCO is instructed to collect a sample. Output from the water level sensors and the record of ISCO sampler activity are transmitted from the remote sampling station to the datalogger at station #1 via a radio link.

Table 1. Universal Transverse Mercator (Zone 11 S) coordinates for equipment installed for the Plutonium Valley runoff transport study.

Instrumentation	Easting	Northing	Elevation
Northern Meteorological Station (#2)	592375	4093665	4,166 ft
Southern Meteorological Station (#1)	592739	4090724	4,066 ft
ISCO Sampler	592751	4091555	4,082 ft

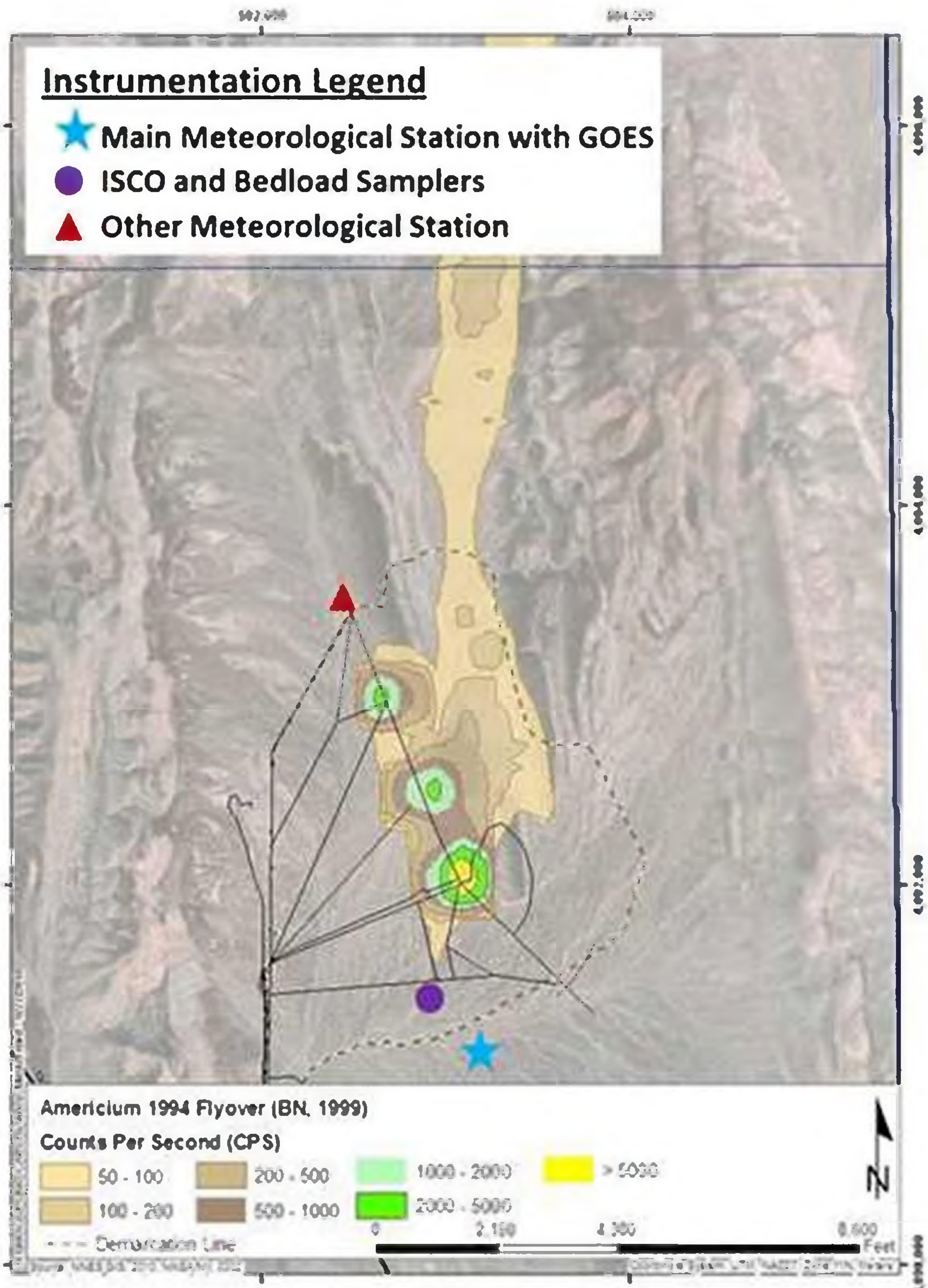

Figure 2. Approximate locations of meteorological stations #1 (blue star) and #2 (red triangle) and ISCO installation (purple circle) in Plutonium Valley, Nevada.

Figure 3. The meteorological stations in Plutonium Valley were installed to measure precipitation, wind, and other meteorological parameters downwind of the Contamination Area during the dominant southerly wind in summer (left: station #2, northern station) and dominant northerly wind in winter (right: station #1, southern station).

Figure 4. The ISCO sampler (inside the orange job box) is triggered when the pressure transducer (yellow cable in the stilling well) detects runoff. The photoacoustic depth sensor (on the left, hanging from the pole) measures flow depth. The wetness sensor (in ground) indicates the presence of moisture. Detection of runoff and flow depth data are relayed by radio signal to the southern meteorological station, and then by GOES satellite to the Western Regional Climate Center.

FISCAL YEAR 2015 OBSERVATIONS

Measurements of air temperature, relative humidity, wind speed and direction, soil volumetric water content, soil temperature, solar radiation, barometric pressure, and precipitation are collected every three seconds. In addition to these typical meteorological measurements, the Plutonium Valley stations are also equipped with a MetOne Particulate Profiler Model 212-1 (Met One Instruments, Grants Pass, OR). Once each minute, the MetOne instrument measures particulate matter suspended in air using light-scattering technology. It is capable of detecting and counting suspended particles in the range of 0.5 to 10 micrometers (µm) (0.00002 to 0.00039 inches) in diameter. The meteorological and particulate data are averaged or totaled, as appropriate, and recorded on the datalogger every 10 minutes. Then, an hourly average is calculated. Because GOES transmission time and data bandwidth are limited, only the hourly average data are transmitted by the GOES system to the WRCC. The GOES transmissions occur at precise time intervals every day and are synchronized using the GPS receiver derived time. The 10-minute data are retained on the datalogger and are manually downloaded during quarterly site visits.

Meteorological Observations

Ten-minute observations collected from the Plutonium Valley southern station (station #1) for the period of October 1, 2014, through September 30, 2015, are summarized by month and year in Table 2, and for the Plutonium Valley northern station (station #2) in Table 3.

During the reporting period (October 1, 2014, through September 30, 2015), the monthly summaries of meteorological data indicate that:

1) The average monthly temperature was warmest in August and coldest in December.
2) The average monthly soil temperature was warmest in July and coldest in December.
3) Monthly average relative humidity was highest in December/January and lowest in June.
4) The monthly precipitation totals at both stations were highest in December at 0.83 inch (21.1 millimeters) (south station #1) and 0.84 inch (21.3 millimeters) (north station #2).
5) The average wind speed was highest in April and May and tended to be the calmest in October through March.

Table 2. Plutonium Valley south station #1 monthly and annual FY2015 (October 2014 through September 2015) metrological data summary.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	ANNUAL	VALUE
Wind Speed Avg (mph)	4.67	4.96	4.49	4.43	5.04	4.76	7.14	6.24	6.05	6.00	5.73	5.76	**AVG**	**5.44**
Wind Speed Max (mph)	20.56	23.74	22.53	18.58	20.78	19.20	27.70	21.66	20.85	23.52	25.54	22.90	**MAX**	**27.70**
Wind Speed Gust (mph)	31.27	34.71	37.04	28.86	32.30	29.23	42.09	35.07	34.27	35.36	35.36	35.88	**MAX**	**42.09**
Air Temperature Avg (deg F)	61.14	46.32	38.71	42.61	48.03	52.92	55.55	62.02	79.11	77.73	79.96	73.59	**AVG**	**59.81**
Air Temperature Min (deg F)	33.27	18.49	9.28	13.17	24.12	21.92	24.27	30.40	47.32	49.48	50.27	41.57	**MIN**	**9.28**
Air Temperature Max (deg F)	88.79	77.77	65.35	71.20	77.20	81.64	83.57	93.04	103.90	98.92	102.00	98.78	**MAX**	**103.90**
Relative Humidity Avg (%)	26.50	33.85	68.49	51.28	41.42	35.90	25.30	37.13	18.07	28.75	26.74	25.88	**AVG**	**34.94**
Relative Humidity Min (%)	4.96	7.55	16.45	9.25	5.52	4.05	5.94	5.89	0.69	3.57	4.88	4.90	**MIN**	**0.69**
Relative Humidity Max (%)	63.82	86.00	100.00	99.50	97.80	99.50	91.30	97.50	77.89	96.40	91.70	76.22	**MAX**	**100.00**
Total Precipitation (inch)	0.00	0.02	0.83	0.42	0.03	0.37	0.13	0.58	0.00	0.48	0.37	0.00	**TOTAL**	**3.23**
Soil Temperature Avg (deg F)	65.09	49.28	40.75	42.36	49.37	55.87	62.46	68.86	85.81	85.35	85.82	79.66	**AVG**	**64.22**
Soil Temperature Min (deg F)	42.47	27.57	24.00	24.33	32.25	31.90	40.01	45.06	60.39	63.34	64.54	55.08	**MIN**	**24.00**
Soil Temperature Max (deg F)	98.22	80.13	65.28	63.27	73.62	87.49	90.63	102.20	119.60	116.70	113.80	111.80	**MAX**	**119.60**
Soil Vol. Water Content Avg[1]	0.14	0.12	0.17	0.18	0.19	0.20	0.18	0.18	0.17	0.15	0.18	0.13	**AVG**	**0.17**
Soil Vol. Water Content Min[1]	0.12	0.11	0.11	0.15	0.17	0.17	0.16	0.16	0.14	0.13	0.14	0.12	**MIN**	**0.11**
Soil Vol. Water Content Max[1]	0.15	0.13	0.20	0.21	0.21	0.22	0.20	0.22	0.21	0.18	0.21	0.15	**MAX**	**0.22**
Solar Radiation Avg (ly)	17.24	12.56	6.27	8.96	13.49	17.68	22.77	18.97	23.20	20.71	19.87	18.73	**AVG**	**16.70**
Solar Radiation Max (ly)	70.96	64.85	46.88	53.84	70.79	90.48	99.77	96.33	90.05	87.90	80.59	73.11	**MAX**	**99.77**
Barometric P. Avg (in Hg)	25.87	25.93	25.91	26.00	25.89	25.92	25.78	25.74	25.78	25.83	25.84	25.82	**AVG**	**25.86**
Barometric P. Min (in Hg)	25.54	25.54	25.47	25.71	25.43	25.61	25.52	25.48	25.61	25.59	25.68	25.61	**MIN**	**25.43**
Barometric P. Max (in Hg)	26.10	26.26	26.18	26.24	26.15	26.17	26.08	25.89	25.93	26.02	26.02	25.96	**MAX**	**26.26**
PM_{10} Avg (μg/m^3)[2]	9.73	5.57	2.53	1.64	4.40	7.40	24.51	10.25	11.56	10.45	10.74	9.38	**AVG**	**9.01**
PM_{10} Max (μg/m^3)[2]	108.30	77.39	254.42	21.04	55.92	108.20	5967.81	326.95	506.70	311.63	149.20	63.81	**MAX**	**5,967.81**
$PM_{2.5}$ Avg (μg/m^3)[2]	2.25	1.48	0.72	0.52	1.41	2.43	6.57	3.42	2.79	2.69	2.84	2.40	**AVG**	**2.46**
$PM_{2.5}$ Max (μg/m^3)[2]	14.05	13.53	28.93	7.13	13.53	25.06	1207.44	23.60	81.32	66.92	22.16	11.78	**MAX**	**1,207.44**

[1] Soil volumetric water content values are relative, which indicates changes through time.

[2] Reported PM_{10} and $PM_{2.5}$ values are estimated using optical particle sizing equipment rather than measurement devices specified in dust concentration regulations.

FY = fiscal year.

Table 3. Plutonium Valley north station #2 monthly and annual FY2015 (October 2014 through September 2015) metrological data summary.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	ANNUAL	VALUE
Wind Speed Avg (mph)	4.73	5.11	4.74	4.91	5.21	5.05	7.00	6.02	5.82	5.92	5.59	5.70	**4.22**	**5.48**
Wind Speed Max (mph)	20.54	25.59	22.78	19.16	20.12	18.05	29.15	21.99	20.94	24.11	25.18	20.89	**4.22**	**29.15**
Wind Speed Gust (mph)	32.30	39.09	35.58	32.00	31.20	31.13	46.03	34.20	32.66	38.07	39.16	32.37	**5.77**	**46.03**
Air Temperature Avg (deg F)	61.51	47.06	39.18	43.47	48.38	53.42	55.33	61.81	78.92	77.58	79.82	73.41	**60.58**	**59.99**
Air Temperature Min (deg F)	34.33	19.58	11.61	13.46	25.81	22.00	23.35	30.76	45.05	50.32	50.79	41.48	**60.58**	**11.61**
Air Temperature Max (deg F)	88.52	78.57	65.35	71.13	76.98	80.78	82.40	92.68	103.80	98.42	102.00	98.04	**60.58**	**103.80**
Relative Humidity Avg (%)	25.54	32.46	66.44	48.78	39.39	33.82	24.91	36.80	18.00	27.79	25.90	25.21	**25.20**	**33.75**
Relative Humidity Min (%)	4.78	6.15	16.26	8.66	5.01	3.27	5.98	5.91	0.72	3.54	4.54	4.77	**25.20**	**0.72**
Relative Humidity Max (%)	63.02	85.00	99.70	99.20	97.40	98.70	88.80	95.90	74.87	93.30	88.70	77.60	**25.20**	**99.70**
Total Precipitation (inch)	0.00	0.01	0.84	0.34	0.03	0.36	0.10	0.67	0.00	0.27	0.26	0.00	**0.00**	**2.88**
Soil Temperature Avg (deg F)	65.38	50.07	41.36	42.64	49.36	55.70	62.61	69.38	85.35	87.02	86.06	79.16	**71.89**	**64.51**
Soil Temperature Min (deg F)	48.96	33.96	29.49	28.55	36.36	34.90	45.46	51.22	64.47	66.38	66.74	60.49	**71.89**	**28.55**
Soil Temperature Max (deg F)	89.37	70.38	58.50	57.11	64.31	78.51	84.20	96.21	110.10	110.40	107.10	102.70	**71.89**	**110.40**
Soil Vol. Water Content Avg[1]	0.05	0.05	0.09	0.08	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.04	**0.04**	**0.06**
Soil Vol. Water Content Min[1]	0.05	0.05	0.05	0.06	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	**0.04**	**0.04**
Soil Vol. Water Content Max[1]	0.06	0.05	0.17	0.10	0.10	0.14	0.07	0.12	0.07	0.07	0.08	0.05	**0.04**	**0.17**
Solar Radiation Avg (ly)	16.68	12.69	8.52	10.60	14.91	17.87	23.94	23.81	26.89	25.97	23.98	19.80	**0.00**	**18.80**
Solar Radiation Max (ly)	73.37	63.22	57.11	58.49	69.76	83.60	99.17	102.90	102.60	99.77	92.38	91.17	**0.00**	**102.90**
Barometric P. Avg (in Hg)	26.56	26.61	26.58	26.69	26.58	26.60	26.45	26.40	26.45	26.51	26.52	26.49	**26.48**	**26.54**
Barometric P. Min (in Hg)	26.20	26.19	26.11	26.38	26.08	26.27	26.17	26.13	26.27	26.25	26.35	26.27	**26.48**	**26.08**
Barometric P. Max (in Hg)	26.80	26.96	26.88	26.95	26.85	26.88	26.78	26.57	26.61	26.71	26.71	26.65	**26.48**	**26.96**
PM_{10} Avg ($\mu g/m^3$)[2]	7.91	4.97	2.51	1.50	3.91	6.40	17.61	8.24	9.40	8.94	9.36	8.33	**AVG**	**7.42**
PM_{10} Max ($\mu g/m^3$)[2]	59.31	120.23	401.17	18.82	69.34	135.75	2707.23	50.45	176.32	508.19	86.68	46.91	**MAX**	**2,707.23**
$PM_{2.5}$ Avg ($\mu g/m^3$)[2]	1.94	1.32	0.62	0.47	1.28	2.15	5.04	2.73	2.19	2.23	2.36	2.03	**AVG**	**2.03**
$PM_{2.5}$ Max ($\mu g/m^3$)[2]	10.37	11.82	19.44	5.82	13.44	23.43	516.88	15.36	25.73	138.81	17.17	11.74	**MAX**	**516.88**

[1] Soil volumetric water content values are relative, which indicates changes through time.

[2] Reported PM_{10} and $PM_{2.5}$ values are estimated using optical particle sizing equipment rather than measurement devices specified in dust concentration regulations.

FY = fiscal year.

The Plutonium Valley monitoring stations generally exhibit similar meteorological conditions, although station #2 is approximately 1.73 miles (2.78 kilometers) north of and 82 feet (25 meters) higher than station #1. Despite the proximity of the two stations, there are significant differences in the topography around the stations that may have a significant influence on local meteorological observations. Station #1 is located east of the valley outlet to Yucca Flat at the widest part of the valley. Stations #2 is located near the north end of the valley where the east and west side mountains are beginning to converge. Daily temperature, relative humidity, and barometric pressure at the two stations track very similarly because of the relatively close proximity. However, the total precipitation at station #1 was 3.23 inches (82.0 millimeters) for the year but 2.88 inches (73.2 millimeters) at station #2 (Tables 2 and 3). This difference may be due to the relative small areal extent of summer thunderstorm cells. Wind directions and speeds also vary between the stations, most likely because of geographic settings. For example, the most common 10-minute wind direction at station #1 is from the south or south-southwest, but at station #2 it is from the north-northwest. The maximum and minimum soil temperatures are slightly more extreme at station #1. Additionally, soil moisture content at the monitoring stations may differ because of the spatial distribution of rainfall and differences in the soil composition, surface slope, and local drainage patterns.

The wind rose graphs shown in Figure 5 illustrate the wind speed and wind direction trends at the Plutonium Valley monitoring stations 1# (south) and #2 (north) during fiscal year (FY) 2015 (October 1, 2014, through September 30, 2015). The graphs on the left side of Figure 5 are based on all winds observed, 0 mph to 40 mph (0 to 64.37 km/hr). The graphs on the right are based on winds above 15 mph (24.14 km/hr). The all-wind roses show that winds between 0 mph and 15 mph (24.14 km/hr) occur most frequently. The frequency of winds is indicated in Figure 6, which shows that winds below 15 mph (24.14 km/hr) occur 96 percent to 97 percent of the time and winds above 15 mph (24.14 km/hr) occur approximately 3.6 percent of the time at station #1 (south) and 2.9 percent of the time at station #2 (north). The wind roses and wind frequency graph (Figures 5 and 6) further indicate that sustained winds above 20 mph (32.19 km/hr) are very infrequent. These winds occur approximately 0.28 percent of time at station #1 and 0.27 percent of time at station #2 (24 hours is equal to 0.274 percent of a year).

Sustained high winds are typically responsible for dust resuspension and dust transport at these sites and it is important to know the frequency, duration, and direction of the higher speed winds to determine when and where the dust transport occurs. The wind rose for station #1 (Figure 5) shows that wind direction may be quite variable coming from the south, east, and north but that westerly winds are significantly less common. At station #2, the wind direction is less variable with most winds coming from the north to northwest or from the south. The lower speed winds are important for establishing this pattern. However, the winds from the south and southwest are clearly dominant for winds that exceed 15 mph (24.14 km/hr). Although there is significant variability in wind direction, especially for lighter winds, the higher winds show a definite pattern of north-south orientation.

Figure 7 shows the frequency distribution of winds above 15 mph (24.14 km/hr), which is based on grouping the wind directions into 10-degree intervals. Southerly winds, between 140 degrees and 220 degrees on the compass rose (between the light green lines in

Figure 7), occur approximately 70 percent of time at station #1 and approximately 66 percent of the time at station #2. Northerly winds, between 300 degrees and 40 degrees on the compass rose (between the purple lines on Figure 7), occur approximately 30 percent of time at station #1 and approximately 34 percent at station #2. This means that when sustained winds above 15 mph (24.14 km/hr) are blowing, the likelihood is well over 95 percent that they are either from the south or north.

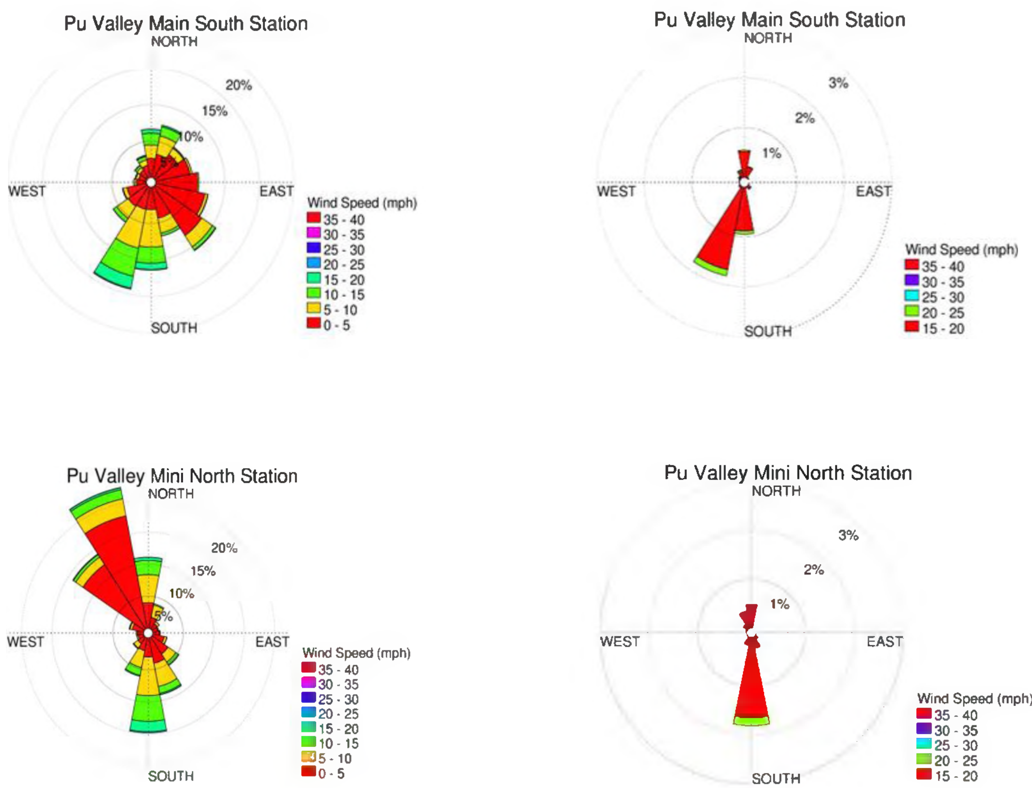

Figure 5. Wind roses representing 10-minute average wind speed and direction for all wind conditions (left) and for winds in excess of 15 mph (24.14 km/hr) (right) observed at stations #1 (south) and #2 (north) in Plutonium Valley during FY2015; 10-minute average wind speeds are calculated from 3-second observations.

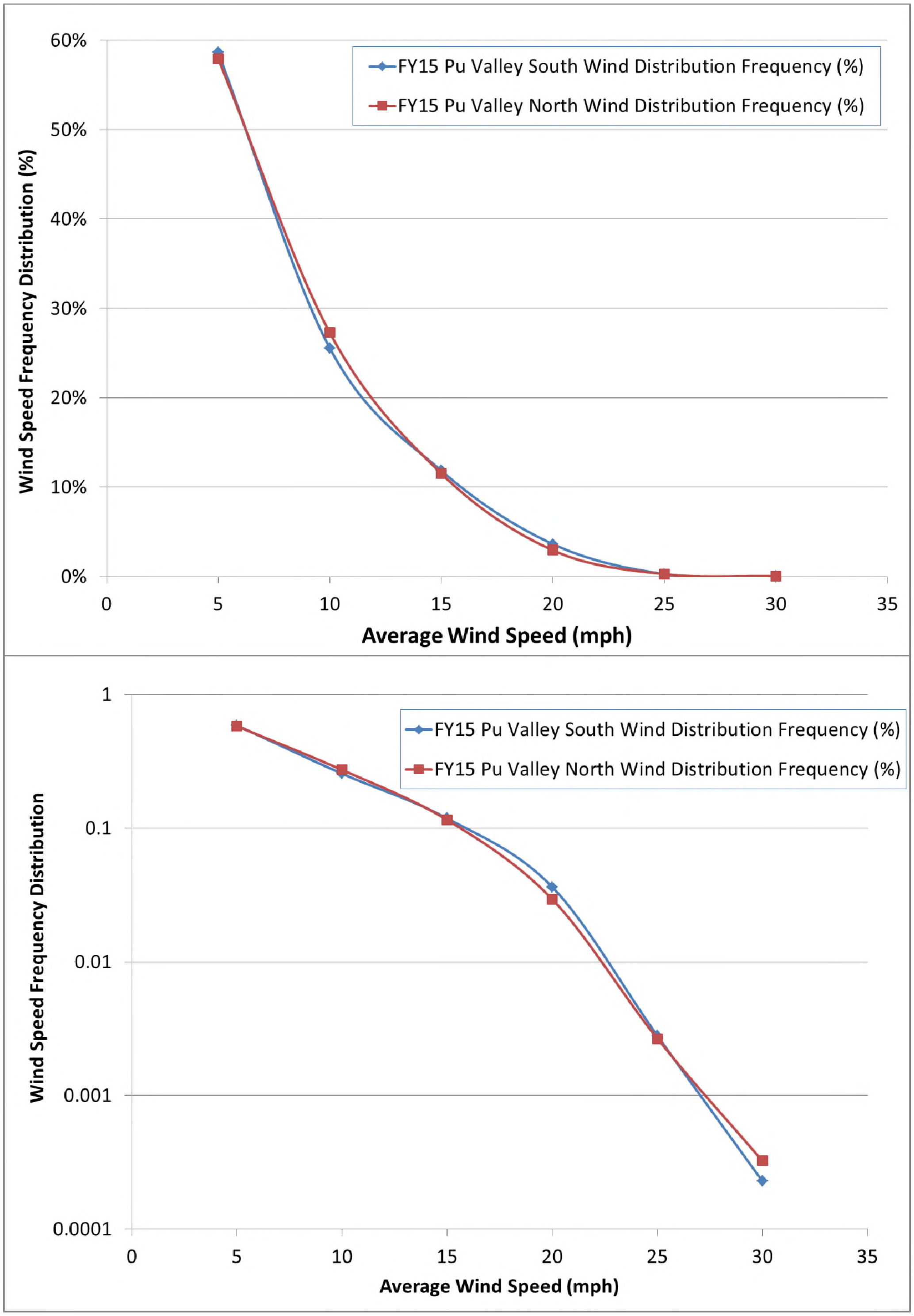

Figure 6. Plutonium Valley stations #1 (south) and #2 (north) FY2015 wind speed distributions. Frequency is plotted on a linear scale in the top graph and on a log scale in the lower graph.

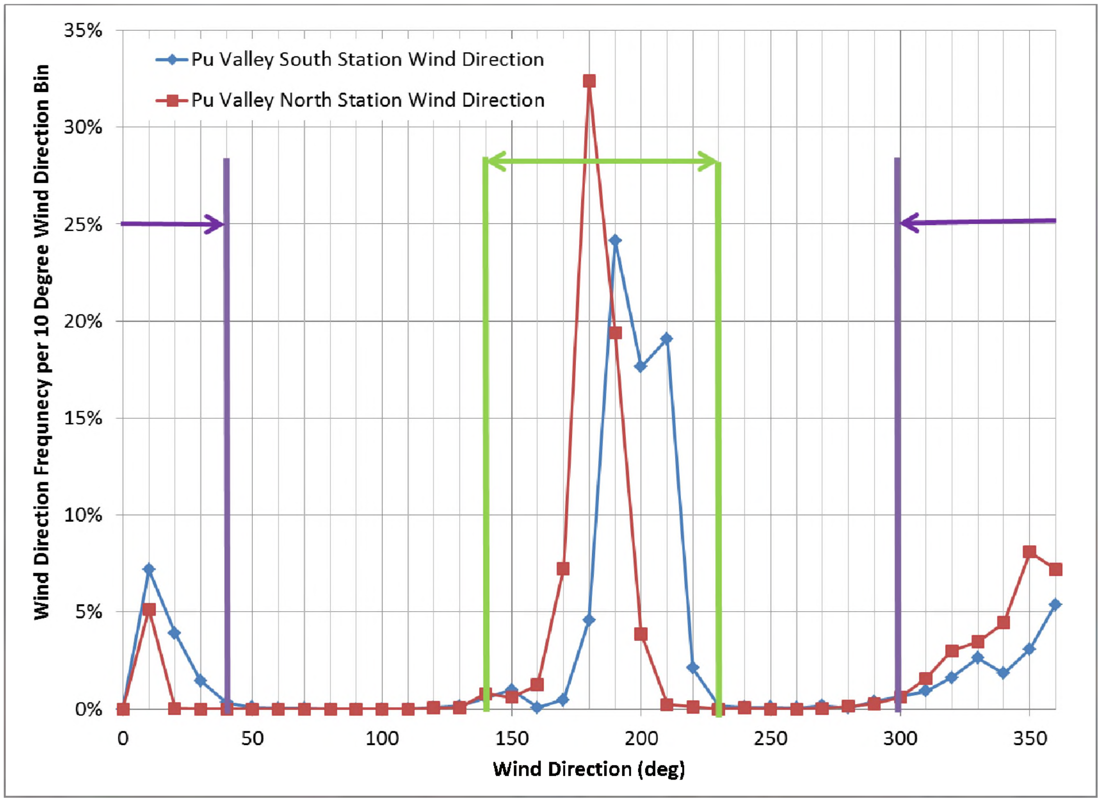

Figure 7. Wind direction frequency for Plutonium Valley stations #1 (south) and #2 (north) for wind speeds over 15 mph (24.14 km/hr), based on grouping the wind directions into 10-degree intervals.

Channel Runoff Observations

Precipitation occurred on numerous occasions during FY2015 (Figure 8) but the 10-minute accumulation exceeded 0.04 inch (1.0 millimeter) on only three days: May 23, July 5, and August 1, 2015, when the daily totals were 0.1 inch (2.5 millimeters), 0.11 inch (2.8 millimeters), and 0.12 inch (3.0 millimeters), respectively. The pressure transducer indicated approximately 1.5 inches (38.1 millimeters) of water in the channel on July 5, 2015, but showed no water presence as a result of the May 23 and August 1, 2015, precipitation events. The wetness sensor, which had been installed on July 15, 2014, exceeded the wetness threshold almost daily between early December 2014 and mid-March 2015. It also showed frequent wet conditions from late April through May and again from early July through early August. The photoacoustic sensor was not reporting at the time the major precipitation events were recorded.

The July 5, 2015, indication of water in the channel in the pressure transducer record peaked approximately 30 minutes after the 10-minute precipitation peaked. The wetness sensor also indicated the presence of water. However, because the depth of water reported by the pressure transducer was less than the ISCO triggering depth (4 inches [101.6 mm]) no runoff water samples were collected for suspended sediment analysis during FY2015.

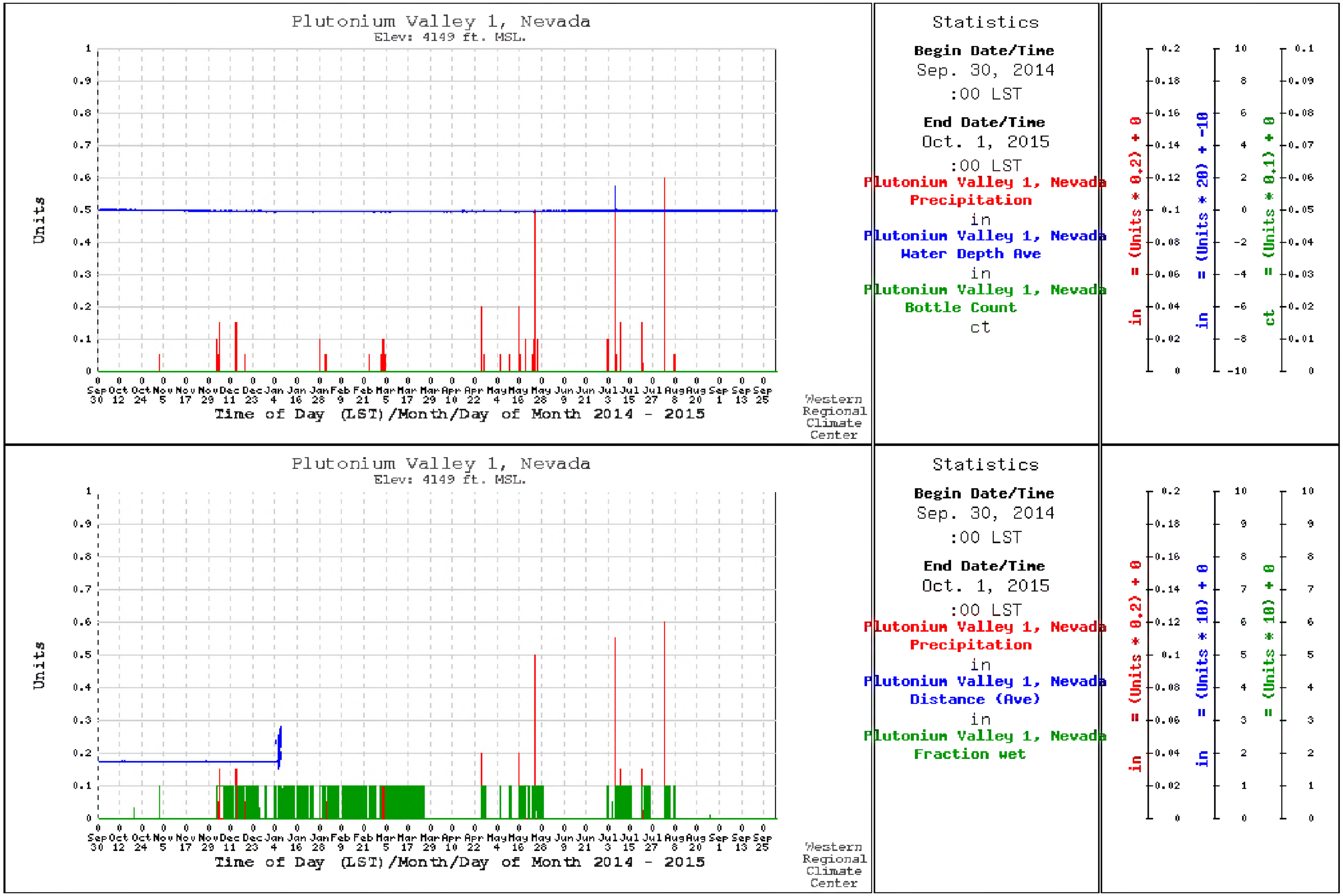

Figure 8. 10-minute precipitation total, depth of water over the pressure transducer, and ISCO bottle count (top graph) and 10-minute precipitation, average distance from the reflection surface to the photoacoustic sensor, and wetness plate value (bottom graph) are shown. The zero bottle count indicates that the ISCO sampler was not activated during FY2015.

Ephemeral Transport Sample Collection

The pressure transducer, photoacoustic sensor, and wetness sensor must each indicate the presence of water in the channel at values in excess of specific thresholds (Appendix C) to initiate the ISCO water sample collection. As shown in Figure 8, the ISCO was not activated and no water samples were collected because the pressure transducer did not indicate water depth greater than the specified threshold (4 inches [101.6 mm]). Additionally, because only minor flow through the channel was indicated during FY2015, no bedload samples were collected during FY2015.

Soil Water Content

Time domain reflectometry values were reviewed to assess the soil response to precipitation. The TDR instruments were not calibrated for the site specific soil conditions, and therefore they do not measure the absolute soil moisture content. However, they do show the relative differences in soil moisture over time at each station. Changes in soil volumetric water content during FY2015 are shown in Figure 9. At station #1, soil moisture content ranged from a minimum of approximately 11 percent to approximately 22 percent. At station #2, the minimum soil moisture content was approximately 4.5 percent and the maximum was approximately 16.5 percent. The minimum moisture content occurred at station #1 in November and at station #2 in September. The highest moisture contents at station #1 occurred in May and August and were associated with large precipitation events. The highest moisture contents at station #2 occurred in December, March, May, and July and were associated with significant precipitation events.

In general, soil moisture at station #1 shows little variability through the winter and spring months and responds to precipitation events in the summer and fall months. During the summer and fall, the soil moisture peaks several days after a major precipitation event, remains high for a few days, and then begins a decline that may flatten out over time. At station #2, soil moisture appears to be more responsive to precipitation events than at station #1. At station #2, moisture content increases quickly and dramatically following even moderate amounts of precipitation and each peak in soil moisture drops sharply immediately following cessation of the precipitation. Definitive changes in soil moisture content appear to occur at station #1 only if the daily precipitation exceeds 0.04 inch (0.1 millimeter), but this responsiveness depends on the antecedent soil moisture conditions. At station #2, the soil appears to retain moisture for much shorter time periods so that the response to precipitation events is much more dramatic. There appears to be a clear change in soil moisture content for precipitation events that exceed 0.01 inch (0.25 millimeter) in one day.

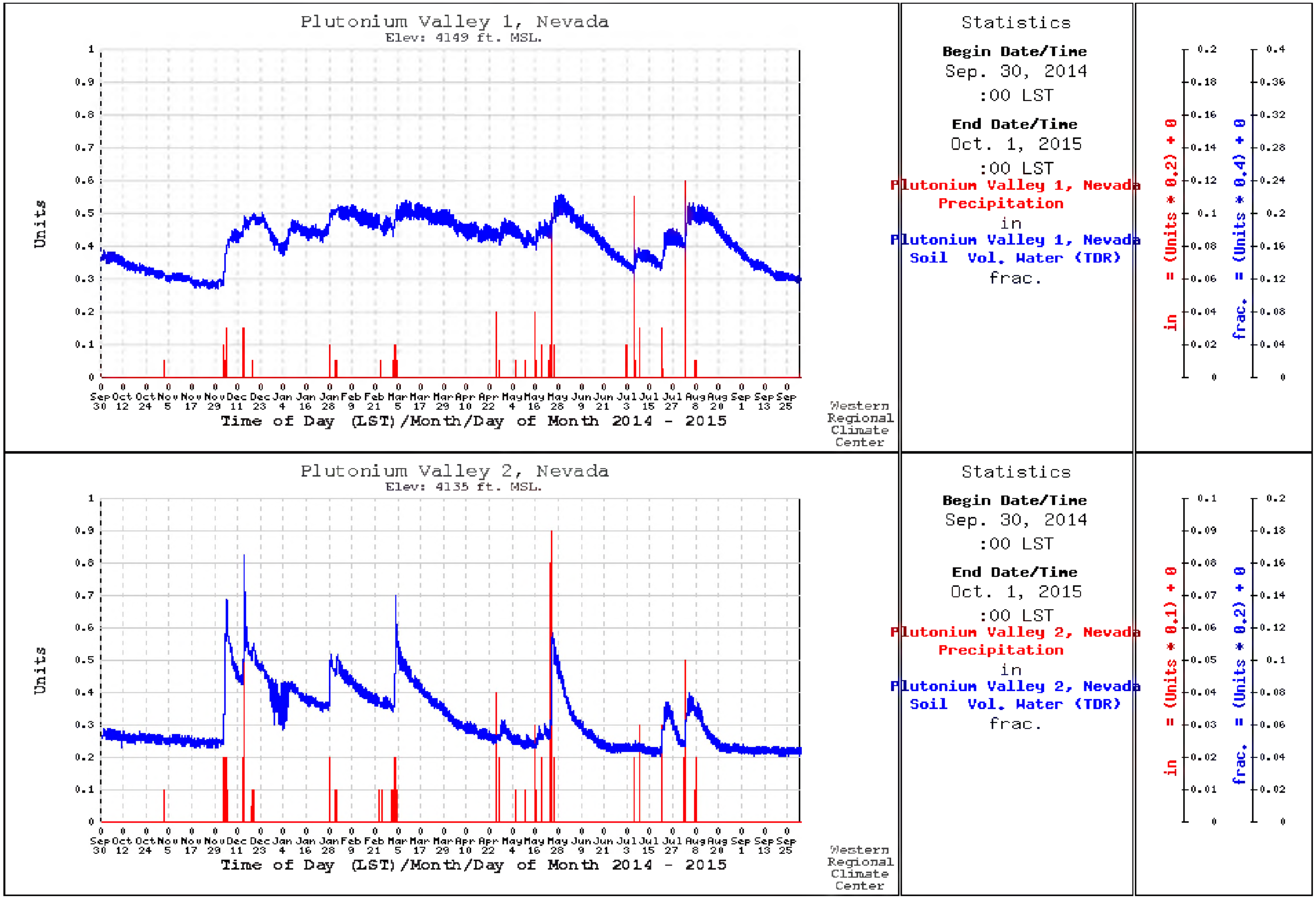

Figure 9. Soil moisture (volumetric water content) observations show changes that reflect precipitation events at Plutonium Valley stations #1 (top) and #2 (bottom) for FY2015.

Aeolian Transport Observations

Because plutonium tends to bind to smaller-sized soil particles (Shinn *et al*., 1993), it is important to assess the prospects of significant aeolian (windborne) transport of sediments from the CA. Sustained high winds are typically responsible for dust resuspension and dust transport at these sites. The wind speed threshold above which aeolian transport occurs is dependent on local conditions such as soil crust strength, extent of soil disturbance, soil moisture, and vegetation cover. Wind speed and airborne particulate matter concentration are compared to evaluate the threshold wind speed at these monitoring stations.

The PM_{10} and $PM_{2.5}$ concentrations quantify the amount of small-sized particles that are suspended in the air and can be easily inhaled in the human respiratory system. MetOne particle profilers are located at both meteorological stations to monitor airborne particle sizes. The counts for particles in eight size ranges between 0.5 µm (0.00002 in) to 10 µm (0.000394 in) are reported every minute and are subsequently averaged and recorded every 10 minutes. The particle counts are converted to a PM_{10} mass concentration in micrograms per cubic meter (µg/m^3). This conversion results in an estimate of PM_{10} that is useful for understanding dust concentrations in the context of other PM_{10} measurements in other locations, but this estimate is not considered accurate enough for regulatory purposes (i.e., for use by the Environmental Protection Agency [EPA] to regulate air quality levels).

Wind speeds and the associated dust concentrations observed at the Plutonium Valley monitoring stations are summarized by 5 mph (24.14 km/hr) wind-speed classes in Tables 4 and 5. Light winds (0 mph to 5 mph [0 km/hr to 24.14 km/hr]) are the most common, occurring 59 percent of the time at station #1 and 58 percent of the time at station #2 during FY2015. Wind speeds in excess of 15 mph (24.14 km/hr) occurred less than 4 percent of the time (less than approximately 350 hours) and wind speeds in excess of 25 mph (40.23 km/hr) occurred less than 0.30 percent of the time (less than approximately 27 hours) at either station during either year. Figure 6 shows the frequencies of occurrence for each wind-speed class, which were similar at both stations.

The PM_{10} concentrations generally increase as wind speed increases but remain fairly low at wind speeds below approximately 15 mph to 20 mph (24.14 km/hr to 32.19 km/hr). Winds are below 20 mph (32.19 km/hr) 97 percent of the time. During FY2015, the PM_{10} concentrations associated with the highest wind-speed class were approximately 2,031 µg/m^3 (2.3×10^{-6} oz/ft^3) at station #1 and 1,159 µg/m^3 (1.31×10^{-5} oz/ft^3) at station #2 (Tables 4 and 5); presumably this difference is due to differences in local conditions at each station but a complete characterization of soil conditions has not been made. High winds and the corresponding high PM_{10} events are relatively rare and generally last for only short periods of time, which is evident from the data shown in Tables 4 and 5.

Table 4. The average $PM_{2.5}$ and PM_{10} concentrations by wind-speed class at Plutonium Valley station #1 (south) during FY2105.

Wind-speed Class (mph)	Duration (hours)	FY15 Pu Valley South Wind Distribution Frequency (%)	FY15 Cumulative Frequency (%)	Average Wind Speed (mph)	FY15 Pu Valley South PM_{10} (µg/m^3)	FY15 Pu Valley South $PM_{2.5}$ (µg/m^3)	FY15 Pu Valley South Ratio PM_{10} (µg/m^3) to $PM_{2.5}$ (µg/m^3)
5	5,137.83	58.650%	58.650%	2.23	7.25	2.06	3.52
10	2,240.33	25.574%	84.224%	6.91	9.03	2.55	3.53
15	1,037.67	11.845%	96.069%	11.69	9.81	2.72	3.60
20	317.83	3.628%	99.697%	16.34	14.54	3.50	4.15
25	24.50	0.280%	99.977%	21.03	136.38	28.20	4.84
30	2.00	0.023%	100.000%	25.58	2,031.08	405.64	5.01

Table 5. The average $PM_{2.5}$ and PM_{10} concentrations by wind-speed class at the Plutonium Valley station #2 (north) during FY2105.

Wind-speed Class (mph)	Duration (hours)	FY15 Pu Valley North Wind Distribution Frequency (%)	FY15 Cumulative Frequency (%)	Average Wind Speed (mph)	FY15 Pu Valley North PM_{10} (µg/m^3)	FY15 Pu Valley North $PM_{2.5}$ (µg/m^3)	FY15 Pu Valley North Ratio PM_{10} (µg/m^3) to $PM_{2.5}$ (µg/m^3)
5	5,076.00	57.944%	57.944%	2.45	6.54	1.81	3.60
10	2,391.00	27.294%	85.238%	6.84	6.91	1.99	3.47
15	1,009.67	11.526%	96.764%	11.65	8.12	2.21	3.68
20	257.33	2.938%	99.701%	16.34	12.24	3.03	4.03
25	23.33	0.266%	99.968%	20.93	51.95	11.67	4.45
30	2.83	0.032%	100.000%	26.57	1,159.00	231.07	5.02

Plots of $PM_{2.5}$ and PM_{10} for FY2015 are shown in Figures 10 and 11, for stations #1 and #2, respectively. At station #1, the daily PM_{10} concentration is below 2.27 x 10^{-8} oz/ft^3 (20 µg/m^3) on most days (Figure 10) and averages approximately 1.08 x 10^{-8} oz/ft^3 (9.5 µg/m^3) for the year; the $PM_{2.5}$ annual average is 2.72 x 10^{-9} oz/ft^3 (2.4 µg/m^3). Figure 11 shows a similar trend of typically low PM_{10} concentrations at station #2 with a few days of high to exceptionally high concentrations. At station #2, the daily average PM_{10} concentration was 8.72 x 10^{-9} oz/ft^3 (7.7 µg/m^3); the daily average $PM_{2.5}$ concentration was 2.2 x 10^{-9} oz/ft^3 (2.0 µg/m^3) (Figure 11). There were four days at station #1 and three days at station #2 when daily average PM_{10} concentrations were high to exceptionally high exceeding 5.66 x 10^{-8} oz/ft^3 (50 µg/m^3). Tables 6 and 7 show the wind conditions at each station on these days. The trend in these high daily average PM_{10} events indicates increasing PM_{10} concentrations with increasing wind speed. However, variation in wind speed explains only approximately 60 to 80 percent of the variation in PM_{10} concentration and there are significant deviations from the general trend especially for the lower wind speed conditions.

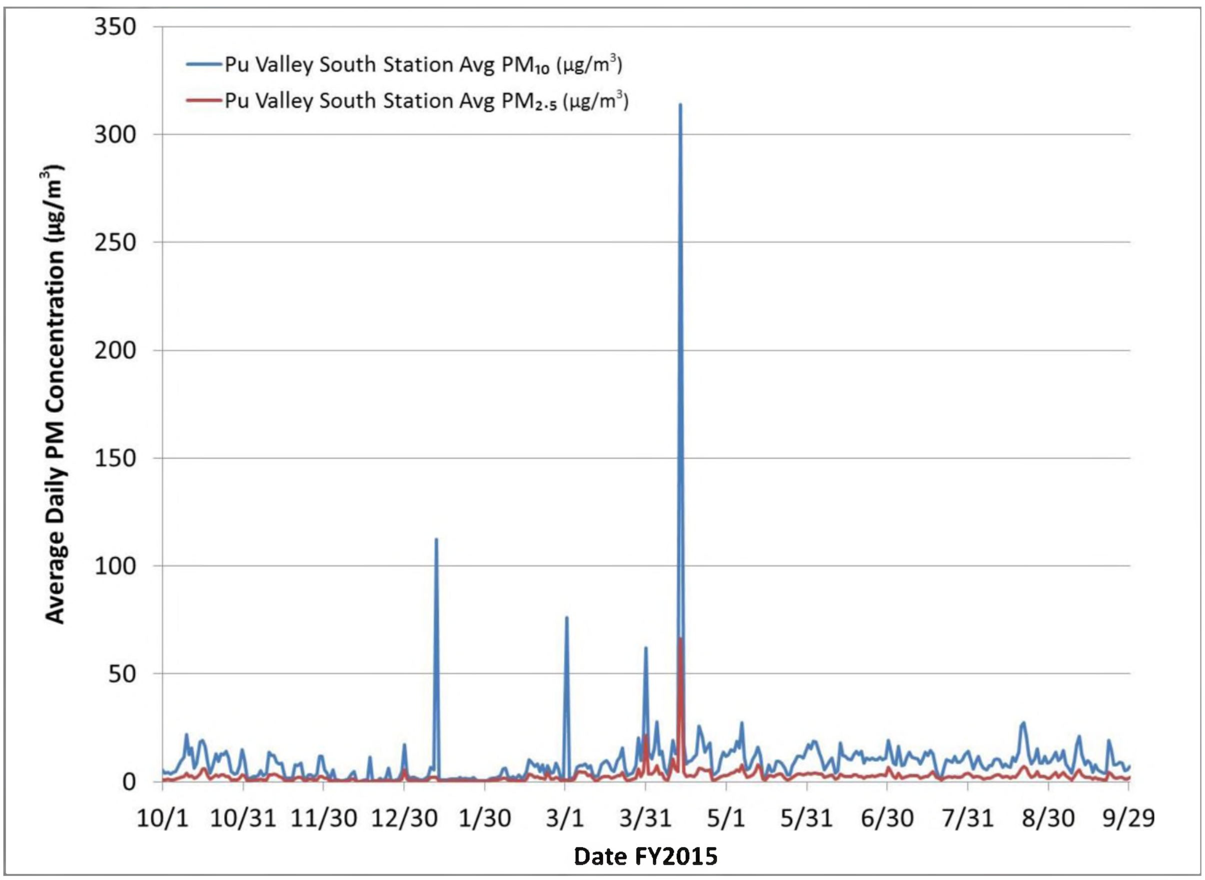

Figure 10. Plutonium Valley station #1 (south) FY2015 daily average $PM_{2.5}$ and PM_{10} concentrations.

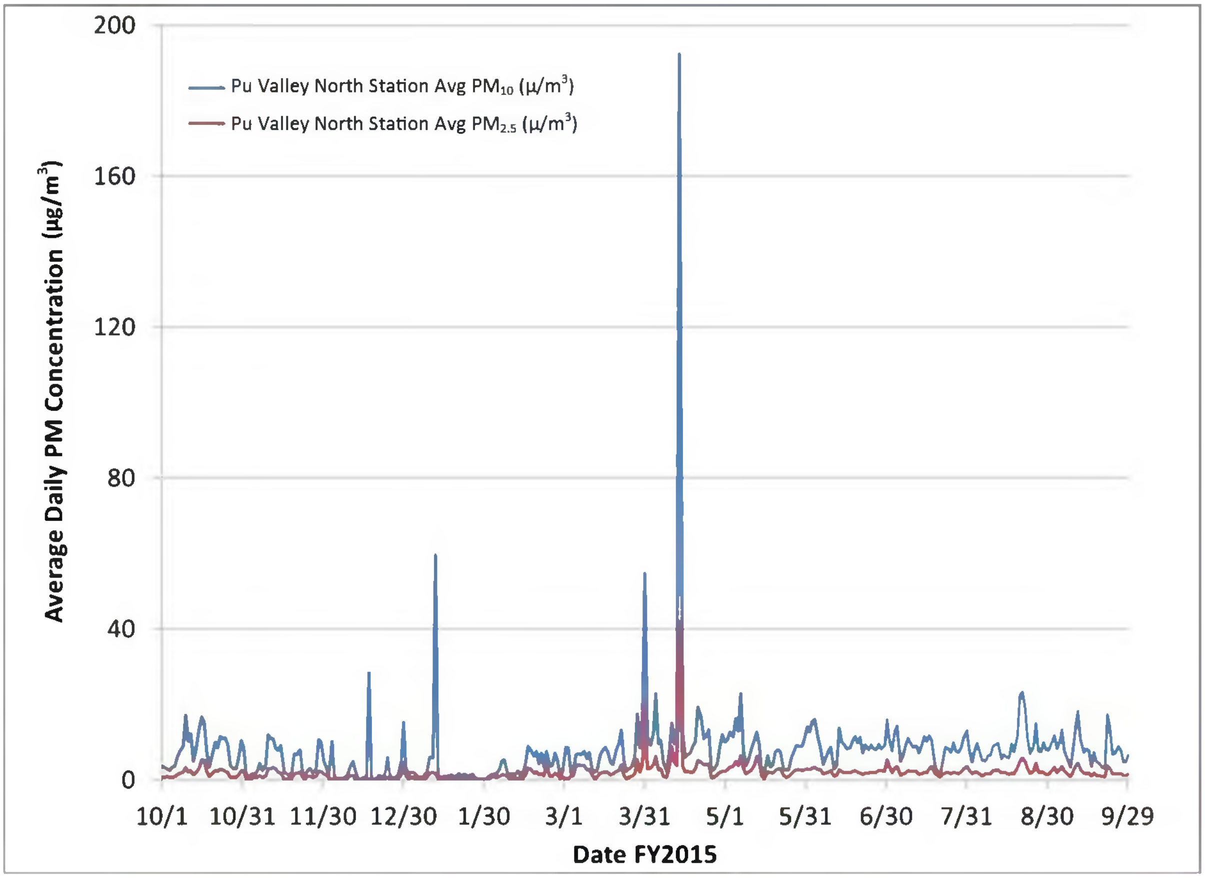

Figure 11. Plutonium Valley station #2 (north) FY2015 daily average $PM_{2.5}$ and PM_{10} concentrations.

For reference, the EPA standard for airborne PM_{10} particulate matter in urban and rural aerosols is a maximum of 1.7 x 10^{-7} oz/ft^3 (150 μg/m^3) averaged over a 24 hour period, which is shown on the EPA's website (http://www.epa.gov/air/criteria.html). Only one daily average PM_{10} concentration value at each station exceeded the EPA standard during FY2015 (Tables 6 and 7).

Table 6. Wind speed (mph) and direction on days when the PM_{10} concentration exceeded 50 μg/m^3 at station #1.

Date	Ave PM_{10}	Ave Wind Speed	Max 10-min Wind Sped	Max Wind Gust	Min 10-min Wind Speed	Wind Direction
Jan 12, 2015	112.28	3.78	10.68	15.86	0.005	SSW to NNW
Mar 2, 2015	75.89	3.37	10.6	15.64	0	SSW to SSE
Apr 1, 2015	61.96	9.79	16.93	27.25	2.167	NNE to SSW
Apr 14, 2015	313.83	15.51	27.7	42.09	2.615	NNW

Table 7. Wind speed (mph) and direction on days when the PM_{10} concentration exceeded 50 µg/m^3 at station #2.

Date	**Ave. PM_{10}**	**Ave Wind Speed**	**Max 10-min Wind Sped**	**Max Wind Gust**	**Min 10-minute Wind Speed**	**Wind Direction**
Jan 12, 2015	59.72	4.06	9.38	14.98	0	S to NNW
Mar 2, 2015	8.64	3.45	11.33	16.07	0.022	SSW to SSE
Apr 1, 2015	54.73	8.64	17.56	29.30	2.396	NNE to NNW
Apr 14, 2015	192.62	14.33	29.15	46.03	0.871	NNW

Figure 12 shows that PM_{10} concentrations increase nonlinearly in response to increases in wind speed. The PM_{10} concentrations at stations #1 and #2 are nearly identical and constant at approximately 1.13 x 10^{-8} oz/ft^3 (10 µg/m^3) for wind speeds below 20 mph (32.19 km/hr). At wind speeds above 20 mph (32.19 km/hr), the PM_{10} concentrations at station #1 are greater than at station #2. Both stations reported PM_{10} concentrations well over 1.13 x 10^{-6} oz/ft^3 (1,000 µg/m^3) for winds in the 25 mph (40.23 km/hr) to 30 mph (48.28 km/hr) wind speed class. There are comparatively few data points at the higher wind speeds, so the PM_{10} averages are more likely to be influenced by greater variability in the observed conditions. Additionally, because the duration of winds in any particular wind speed class is slightly different at stations #1 and #2 (Tables 4 and 5), the PM_{10} concentrations for each wind speed class at the two stations are not derived from exactly the same wind conditions. For these reasons, relatively large differences between the two stations are more likely to appear at higher wind speeds. Also, it is important to note that the higher wind speeds occur infrequently and last for only short time periods (Tables 4 and 5), which suggests that major dust-generating winds are relatively rare events.

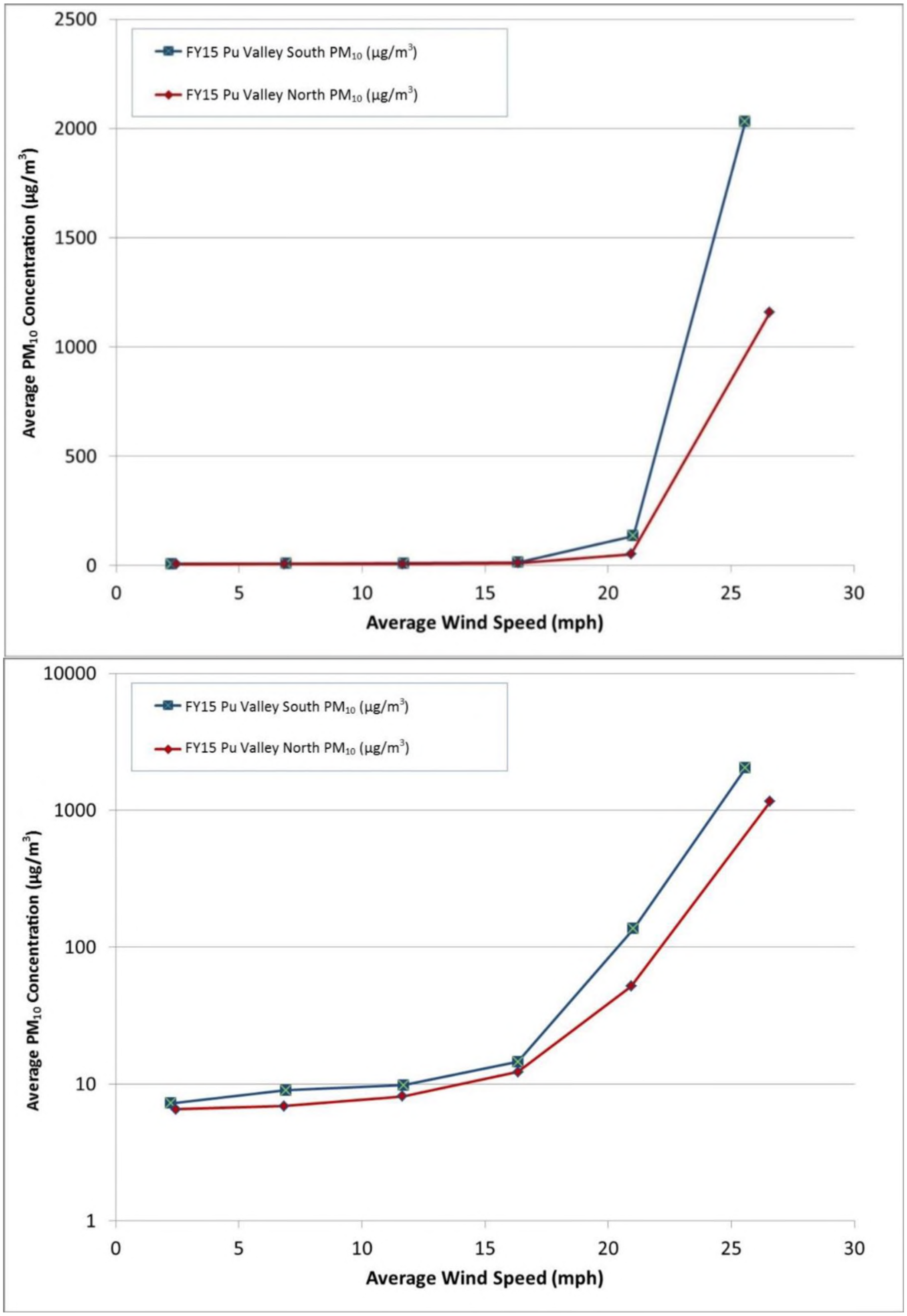

Figure 12. Plotting PM_{10} concentration (on linear scale in top graph and log scale in bottom graph) against the average wind speed for each wind-speed class reveals that the PM_{10} concentration increases approximately exponentially with increasing wind speed.

The PM_{10} roses for both Plutonium Valley monitoring stations are shown in Figure 13. This figure is similar to a wind rose except that the PM_{10} rose shows PM_{10} concentration frequency instead of wind speed frequency for specific wind directions. Higher PM_{10} concentrations occur with greater frequency in association with the north and south wind directions. The orientation of the PM_{10} concentration frequency is similar to the orientation of wind speed frequency (Figure 5). Both the higher wind speeds and higher PM_{10} concentrations are associated with the southerly wind direction. Although easterly winds occur less frequently and at lower speeds, there are substantial dust concentrations associated with them. At both meteorological monitoring stations, PM_{10} concentrations are fairly low (below 1.13×10^{-8} oz/ft^3 [10 µg/m^3]) 80 percent to 85 percent of the time, which indicates relatively stable surface conditions and approximates natural background levels for PM_{10} concentration.

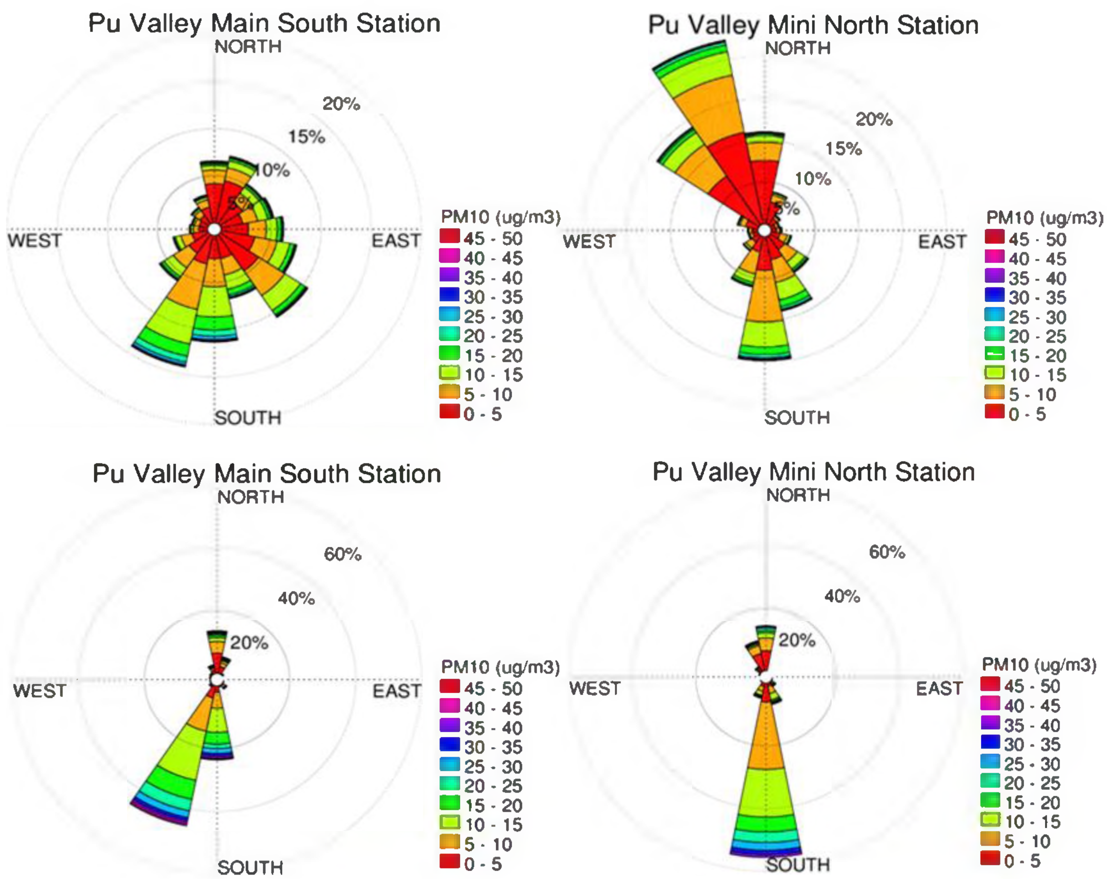

Figure 13. PM_{10} rose diagrams that show the distribution of PM_{10} for all 10-minute average wind speeds (top) and for 10-minute average wind speeds greater than 15 mph (24.14 km/hr) (bottom) at stations #1 (south) and #2 (north) during FY2015.

Figure 13 also shows the PM_{10} concentrations associated with wind speeds in excess of 15 mph (24.14 km/hr). At higher wind speeds, there is a greater potential for higher PM_{10} concentrations (Figure 12). At both monitoring stations, when the wind speeds exceed 15 mph (24.14 km/hr), the PM_{10} concentrations are significantly greater than when wind speeds are less than 15 mph (24.14 km/hr). The PM_{10} concentrations range from 9.06×10^{-9} oz/ft^3 to 2.3×10^{-6} oz/ft^3 (8 µg/m^3 to 2,031 µg/m^3) (Tables 4 and 5) when wind speeds exceed 15 mph (24.14 km/hr).

PM_{10} to $PM_{2.5}$ Ratio: Source Proximity for Observed Dust Conditions

The $PM_{2.5}$ fraction of the FY2015 airborne dust was analyzed in a manner similar to the PM_{10} analyses described above. The $PM_{2.5}$ dust concentration is associated with wind-speed classes in Tables 4 and 5. Figure 14 shows the relationship between $PM_{2.5}$ concentration and wind-speed class for FY2015. The $PM_{2.5}$ dust concentration (Figure 14) also exhibits an approximately exponential relationship with wind speed that is similar to the PM_{10} dust concentration (Figure 12). The difference in $PM_{2.5}$ concentrations between stations #1 and #2 is negligible for wind speeds below 20 mph. At wind speeds above 20 mph (32.19 km/hr), station #2 recorded slightly less $PM_{2.5}$ concentrations relative to station #1 in FY2015.

The ratio between PM_{10} and $PM_{2.5}$ is a qualitative indication of the proximity of the dust source to the location where the dust concentration is measured. By definition, PM_{10} includes larger suspended dust particles than $PM_{2.5}$. Therefore, PM_{10} concentration decreases with distance from the source more quickly than $PM_{2.5}$ concentration and observations near the dust source will have a high PM_{10} to $PM_{2.5}$ ratio. Figure 15 shows that the PM_{10} to $PM_{2.5}$ ratio is approximately 3.5 for winds below 15 mph but it increases to approximately 5 for winds approaching 30 mph (48.28 km/hr). This increase in the ratio is an indication that some suspension and transport of locally derived dust and soil is occurring but because winds near 30 mph (48.28 km/hr) occur less than 0.03 percent of the time the duration of higher PM_{10} concentrations is small.

Figure 7 shows that sustained winds greater than 15 mph are from the south (140 degrees to 230 degrees) more than 68 percent of the time and from the north (300 degrees to 40 degrees) approximately 37 percent of the time. Wind and dust data were separated into these two wind direction groups so that the dataset could be compared with the associated dust transport. At both stations #1 and #2, Figures 16 and 17, respectvely, show that southerly winds have higher average PM_{10} concentrations when wind speed is below 15 mph, but this relationship reverses for winds greater than 15 mph (24.14 km/hr) when northerly winds have higher PM_{10} concentrations. Therefore, winds blowing from the south dominate the annual average PM_{10} concentration for winds below 15 mph (24.14 km/hr), but winds blowing from the north dominate the average annual PM_{10} concentration for winds over 15 mph (24.14 km/hr). It is also important to note that in FY2015 sustained winds greater than 25 mph (40.23 km/hr) only came from the north.

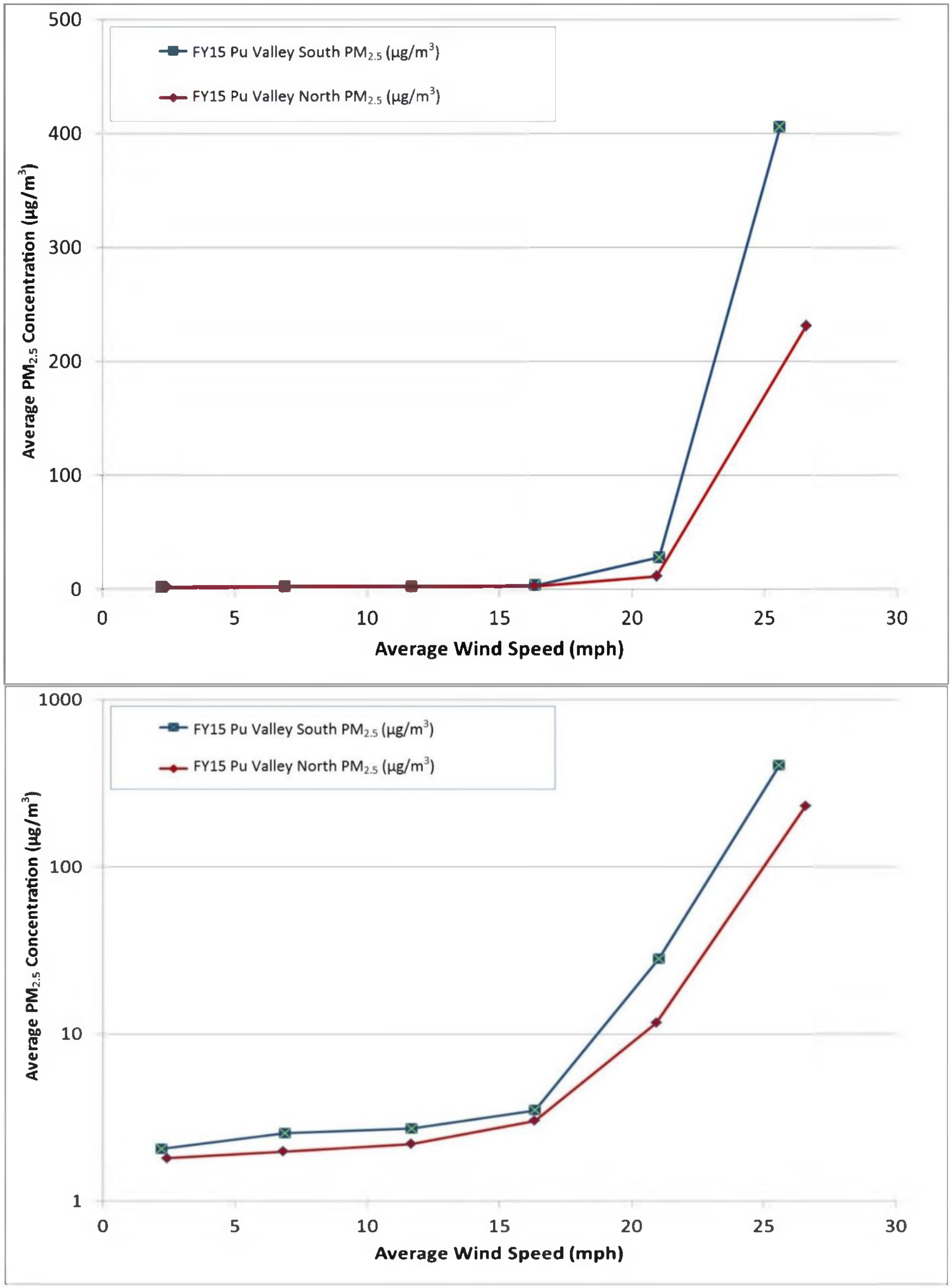

Figure 14. Plutonium Valley stations #1 (south) and #2 (north) FY2015 $PM_{2.5}$ concentration (linear scale in top graph and log scale in bottom graph) versus average wind speed.

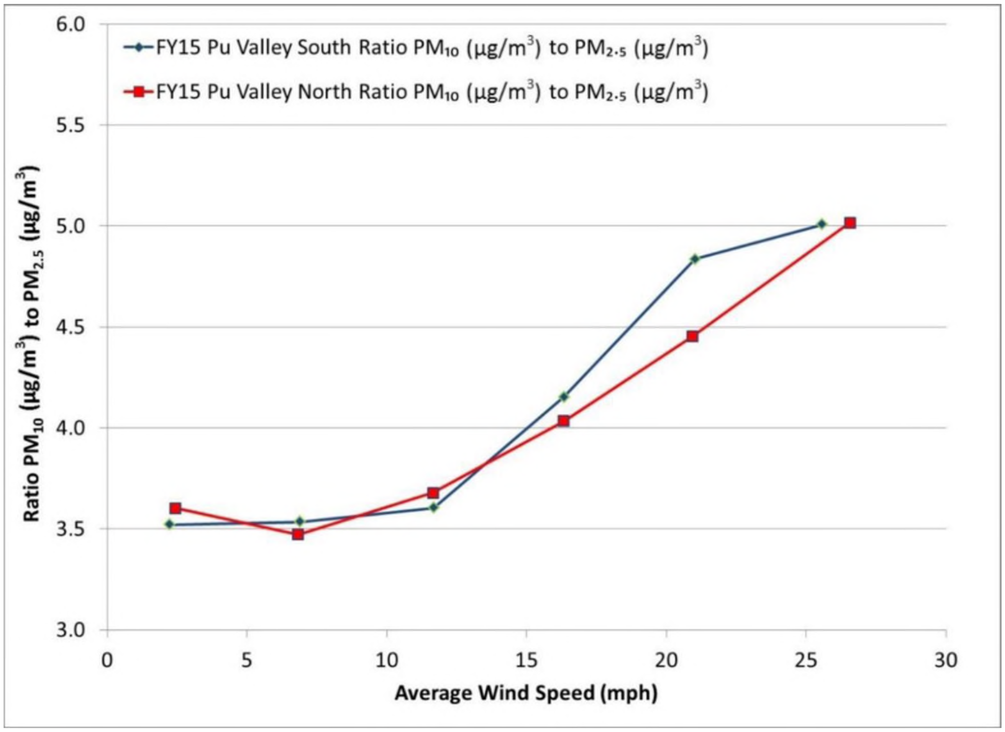

Figure 15. Plutonium Valley stations #1 (south) and #2 (north) FY2015 PM_{10} to $PM_{2.5}$ ratio versus average wind-speed class.

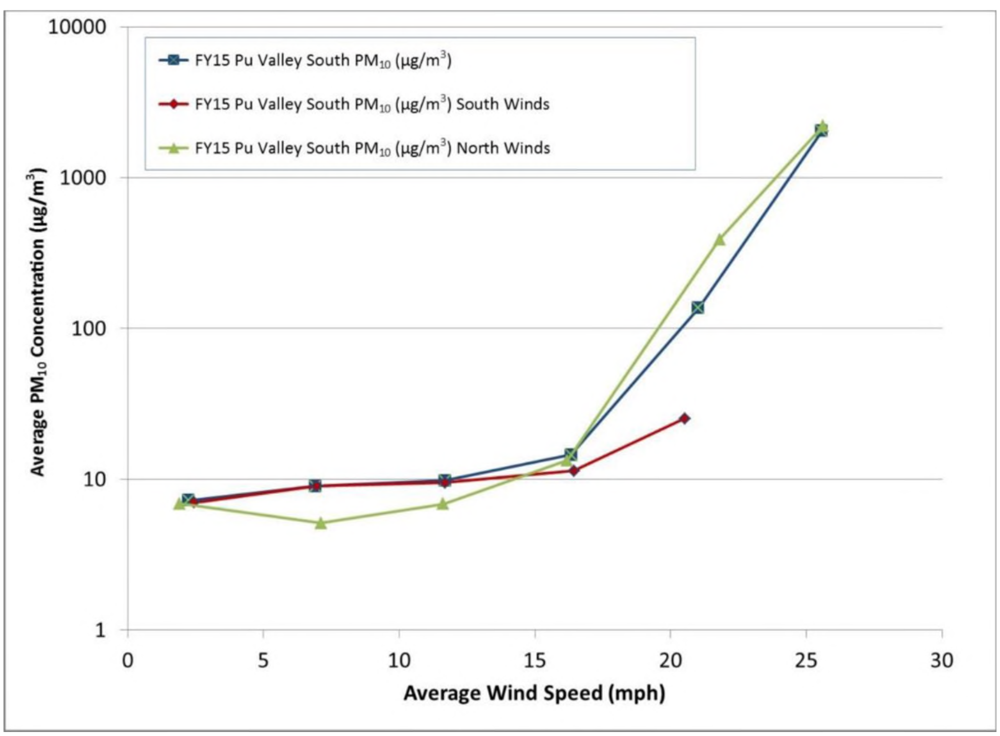

Figure 16. Plutonium Valley station #1 (south) FY2015 PM_{10} concentration (log scale) versus average wind speed for northerly and southerly winds.

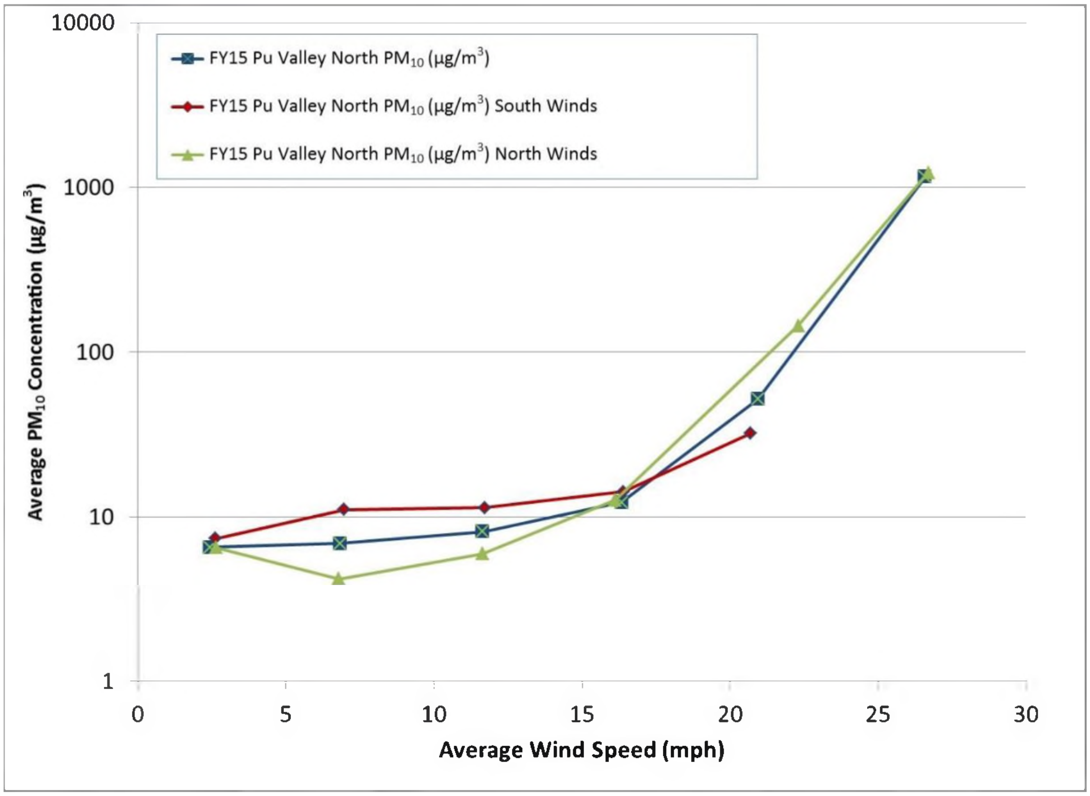

Figure 17. Plutonium Valley station #2 (north) FY2015 PM_{10} concentration (log scale) versus average wind speed for northerly and southerly winds.

Four major dust events, indicated by significant increases in PM_{10} concentrations, were identified in FY2015. Figures 18 through 21 show the common relationships between dust concentration and wind speed. As with average wind and dust conditions, these individual events indicate that elevated dust concentrations are associated with increasing or high wind conditions. In general:

1. Wind speeds at the two Plutonium Valley monitoring stations were similar during these events; this might be expected because of the proximity of the stations.
2. Wind events lasted between 5 hours and 24 hours.
3. Maximum PM_{10} dust concentrations usually occurred in conjunction with the strongest winds during these events.
4. There is a strong similarity in the dust concentrations at both monitoring stations. Only one of the four events shows a difference between the stations, with station #1 showing greater dust concentration during the April 14, 2015, event.
5. Background dust concentrations are less than 7.93 x 10^{-9} oz/ft^3 (7 µg/m^3) at wind speeds below 3 mph (4.83 km/hr).

6. Dust concentrations began to increase as soon as wind speeds increased, but high dust concentrations are associated with winds greater than approximately 15 mph (24.14 km/hr).
7. The highest dust concentrations are generally associated with the onset and early periods of high wind speeds.
8. Dust resuspension events were observed during June through August 2015, when soils are dry and winds are fairly light.
9. A decline in dust concentrations before the winds diminish suggests that the available mobile dust fraction is easily exhausted during individual wind events and additional dust generation depends on stronger winds or other phenomena that break up aggregated dust particles.

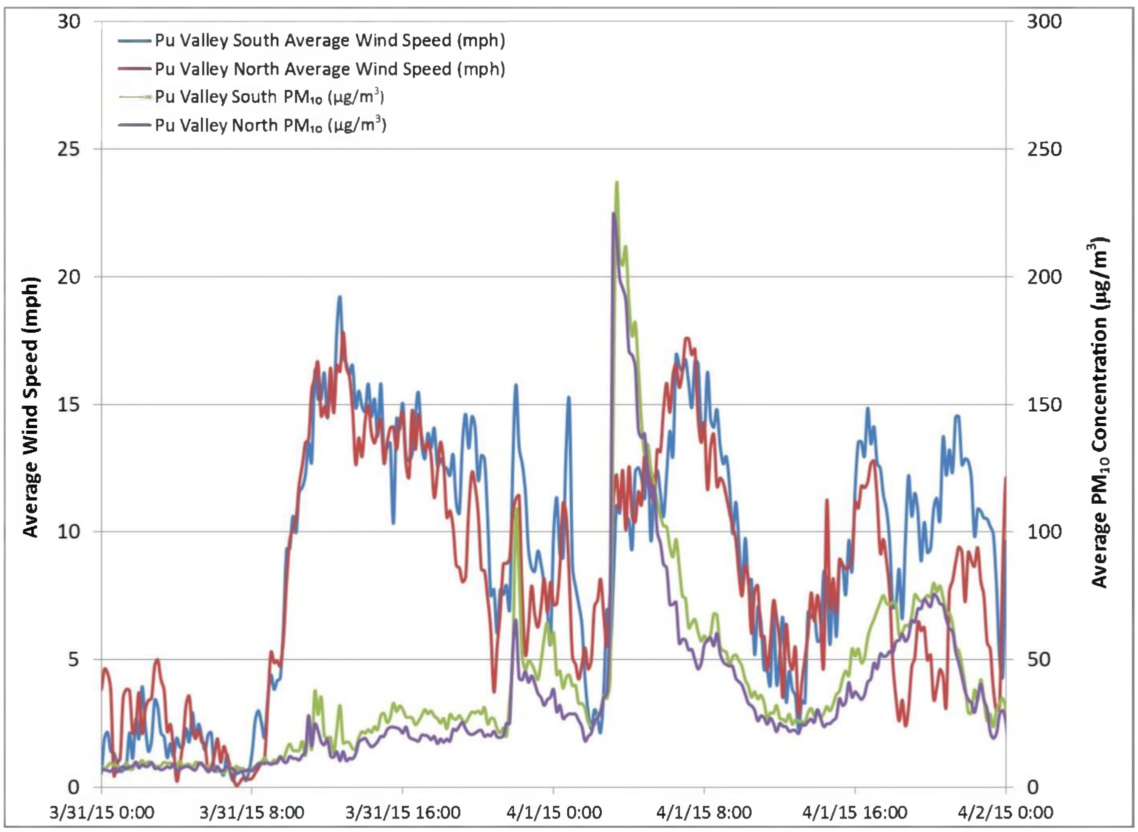

Figure 18. The wind event between March 31 and April 1, 2015, lasted approximately 24 hours. Maximum sustained 10-minute winds were between 15 mph (24.14 km/hr) and 20 mph (32.19 km/hr) and occurred during the morning hours on March 31 and April 1, 2015. The PM_{10} concentrations at the monitoring stations were very similar.

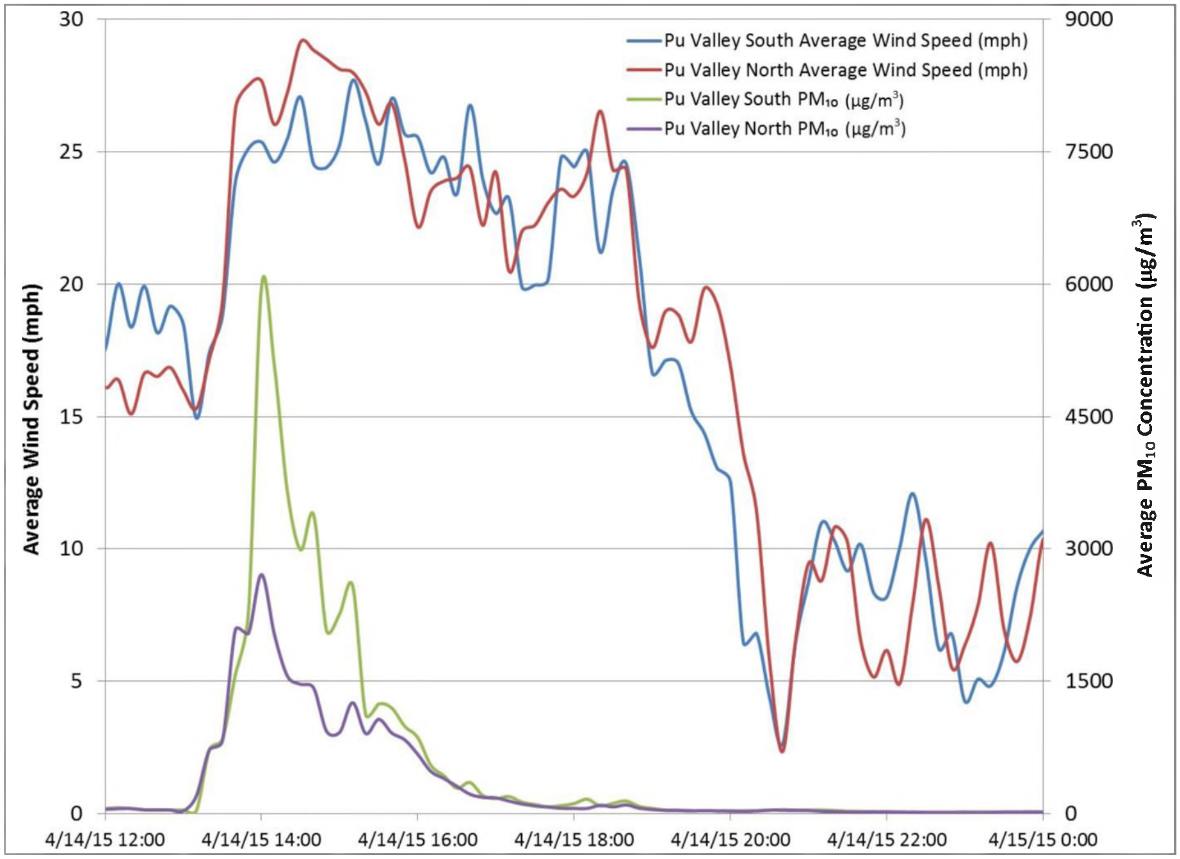

Figure 19. The wind event recorded on April 14, 2015, was by far the strongest event of the year both in terms of sustained wind speed and PM_{10} concentration. The sustained 10-minute wind speeds were in excess of 25 mph (32.19 km/hr) when the highest PM_{10} concentrations were recorded. The highest PM_{10} concentration at station #1 (south) was approximately 6.80 x 10^{-6} oz/ft^3 (6,000 µg/m^3) and it was approximately 3.17 x 10^{-6} oz/ft^3 (2,800 µg/m^3) at station #2 (north). The highest PM_{10} concentrations were recorded at 2:10 pm; PM_{10} concentrations above 4.53 x 10^{-8} oz/ft^3 (40 µg/m^3) lasted for approximately 6 hours, between 1:10 pm and 7:00 pm. This dust event was regional in extent and monitoring stations at the Tonopah Test Range (approximately 65 miles to the northwest) recorded elevated PM_{10} during the same time period. This dust event is typical of springtime events between March and May, when strong wind episodes are responsible for the suspension and transport of soil material.

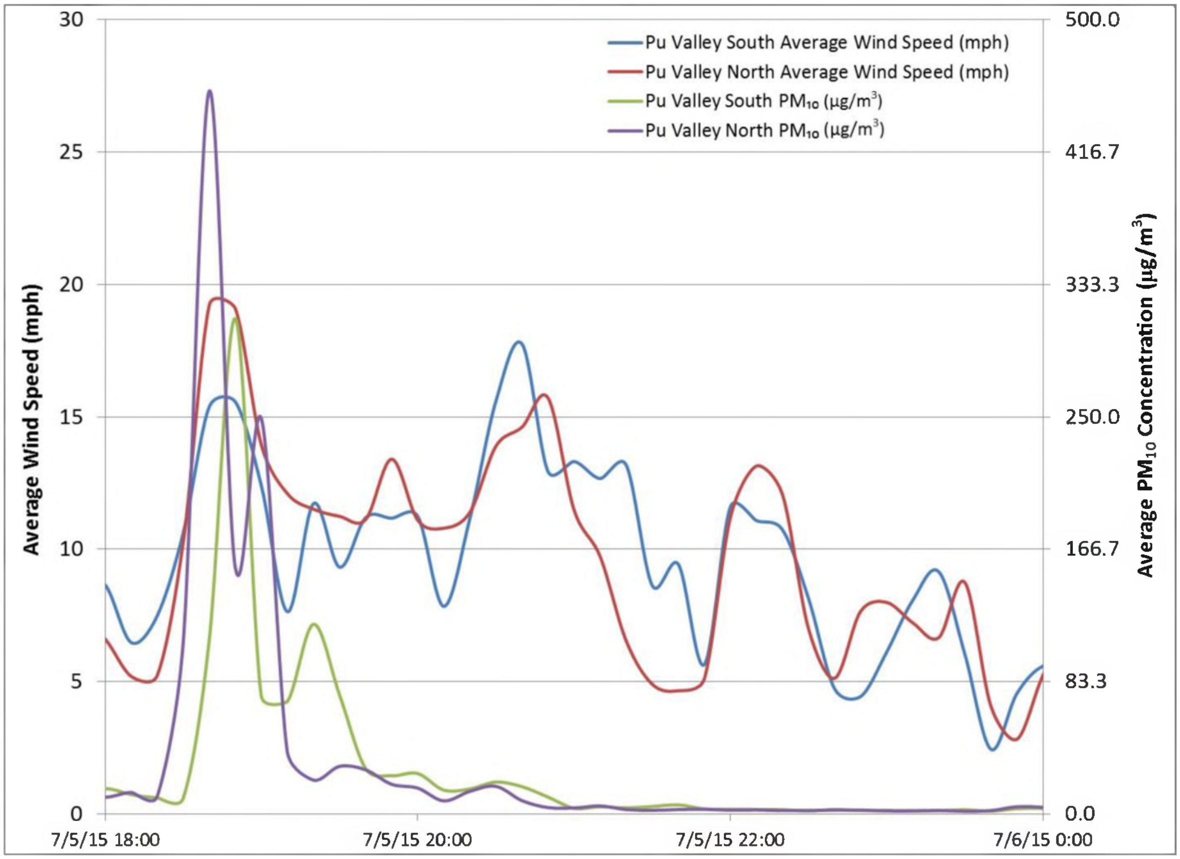

Figure 20. The dust event recorded on July 5, 2015, is more typical of summer dust transport when soil moisture content is lowest and vegetation is sparse. Relatively minor and short increases in wind speeds resulted in an elevated PM_{10} concentration. The wind speed exceeded the threshold of fine dust deposits, which were resuspended and transported relatively short distances because the wind speed did not remain above the threshold for very long. Because the soil moisture content was low, freshly deposited dust remains relatively unbound and available for resuspension. The maximum observed PM_{10} concentration for the 10-minute period was 455 µg/m^3 for station #2 (north).

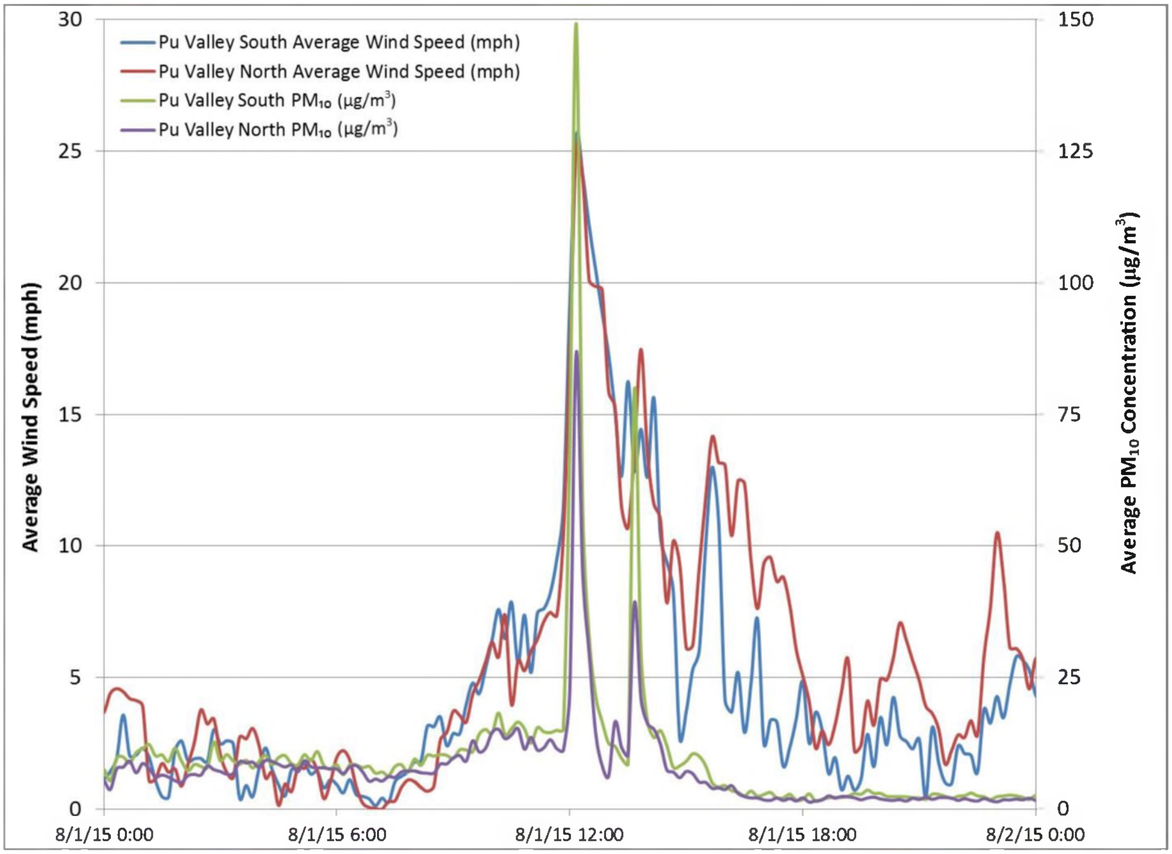

Figure 21. The dust event recorded on August 1, 2015, is another example of a summer wind event when soils were dry. The PM_{10} increase occurred between 11:50 am and 12:15 pm, and also between and 1:40 pm and 2:00 pm. The short duration of PM_{10} increase is partly because of the limited supply of deposited dust and also because of the relatively short period of increasing wind speed. The correlation between the two monitoring stations was high for both wind speed and PM_{10} concentration and the maximum observed PM_{10} concentration was close to 1.7×10^{-7} oz/ft^3 (150 µg/m^3) when winds reached 25 mph (40.23 km/hr) for one 10-minute period.

CONCLUSIONS

Elevated wind speed and precipitation are the meteorological parameters most related to the migration of contaminated soil particles. During FY2015, a period of high wind speeds was observed in the spring and the largest precipitation events were recorded in December, May, and July. Annual total perception was approximately 3.0 inches (76.2 millimeters) at each of the two monitoring stations. This total was below the long-term annual average and resulted in drier soils than typically observed. These conditions coupled with stronger than average winds in April resulted in the strong dust event recorded on April 14, 2015. Differences between wind speed, wind direction, and precipitation observations at meteorological stations #1 (south) and #2 (north) reflect the notable spatial variability of meteorological conditions observed in southwestern desert climates.

Although increases in PM_{10} concentration are observed at wind speeds of approximately 15 mph (24.14 km/hr), there is a sharp increase in PM_{10} concentrations as the wind speed exceeds to 20 mph (32.19 km/hr). This is reflected in the changing slope of the lines for both stations in Figure 13. Records show that the relationship between airborne dust and wind speed is similar at both meteorological stations. The highest dust concentrations in air appear to occur during short periods of time when the wind speed is greater than 20 mph (32.19 km/hr). However, wind speeds above 20 mph (32.19 km/hr), occurred less than 4 percent of the time in FY2015. Additionally, the dust concentrations diminished before wind speeds dropped off suggesting that the surface soils are generally stable. Natural processes, for example, rain drop impact, animal movement, may loosen soil particles but the dust available for resuspension at any time is limited. The maximum observed PM_{10} daily average concentrations were in the range of 2.15 x 10^{-7} oz/ft^3 to 3.57 x 10^{-7} oz/ft^3 (190 μg/m^3 to 315 μg/m^3) on April 14, 2015, which is slightly above the 24 hour average PM_{10} standard of 1.7 x 10^{-7} oz/ft^3 (150 μg/m^3) set by the EPA for urban areas and rural communities. Thus, workers, if in the vicinity of the CA, may be subject to high concentrations of airborne dust for during the early portions of wind events that exceed 15 to 20 mph. After the available dust particles have been resuspended, dust concentrations diminish until other phenomena, such as raindrop impact and animal activity, cause soil particles on the soil surface to separate.

Numerous precipitation events are shown in the data record for FY2015. The two largest maximum hourly precipitation totals of approximately 0.23 inch (5.8 millimeters) and 0.16 inch (4.1 millimeters) resulted from thunderstorm events in July and August. Most events produced less than 0.15 inch (3.8 millimeters) in a one hour period. Although water was detected by the pressure transducer and wetness sensor, there was not enough water present for the ISCO sampler to activate and collect a runoff sample for suspended sediment analysis, nor were any bedload samples collected during FY2015.

FUTURE WORK

Data transmitted from the Plutonium Valley monitoring stations will be reviewed monthly by project personnel to identify precipitation events that exceed the specified rainfall threshold (~0.2 inch [0.5 centimeter]) assumed to result in potential runoff and to assess the proper operation of the instrumentation and remote communication equipment. Field inspections will be scheduled to service instrumentation only if necessary.

If the rainfall threshold is exceeded, the pressure transducer, photoacoustic, and wetness sensor outputs will be reviewed to determine if sufficient water was present in the channel to cause the ISCO to turn on and collect a sample of runoff water for suspended sediment analysis. In response to a runoff event that triggers the ISCO sampler, project personnel will recover the collected water and bedload samples. These samples will be submitted to a specified laboratory to determine particle size distribution and radionuclide concentrations. These data will help establish relationships between the sediment eroded and transported during runoff events and the significance of channel runoff as a pathway for radionuclide migration from the CAU.

Additionally, meteorological data collected leading up to and during the runoff event will be analyzed to characterize the meteorological conditions that produced the runoff. This analysis will help delineate threshold conditions that are likely to result in sediment transport and the migration of radionuclide-contaminated soils. Establishing these thresholds will help identify meteorological conditions that may trigger monitoring and sampling of channel runoff migration pathways. Requirements for monitoring meteorological conditions and for sampling runoff pathways can then be appropriately incorporated in closure plans. Meteorological data, particularly wind data and soil moisture content, will continue to be compared against the airborne particulate matter data to determine PM_{10} transport in conjunction with wind events.

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Colton, D., 1999. A series of low-altitude aerial radiological surveys of selected regions within areas 3, 5, 8, 9, 11, 18, and 25 at the Nevada Test Site. DOE/NV/11718-362, prepared for the U.S. Department of Energy, Nevada Operations Office by Bechtel Nevada.

Shinn, J.H., F.J. Gouveia, S.E. Patton, and C.O. Fry, 1993. Area 11 Case Study of Radionuclide Movement by Storm Channel Erosion: A Baseline Method and Initial Evaluation. Prepared for the U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

APPENDIX A: FY2015 CHARTS OF METEOROLOGICAL OBSERVATIONS AT PLUTONIUM VALLEY STATION #1

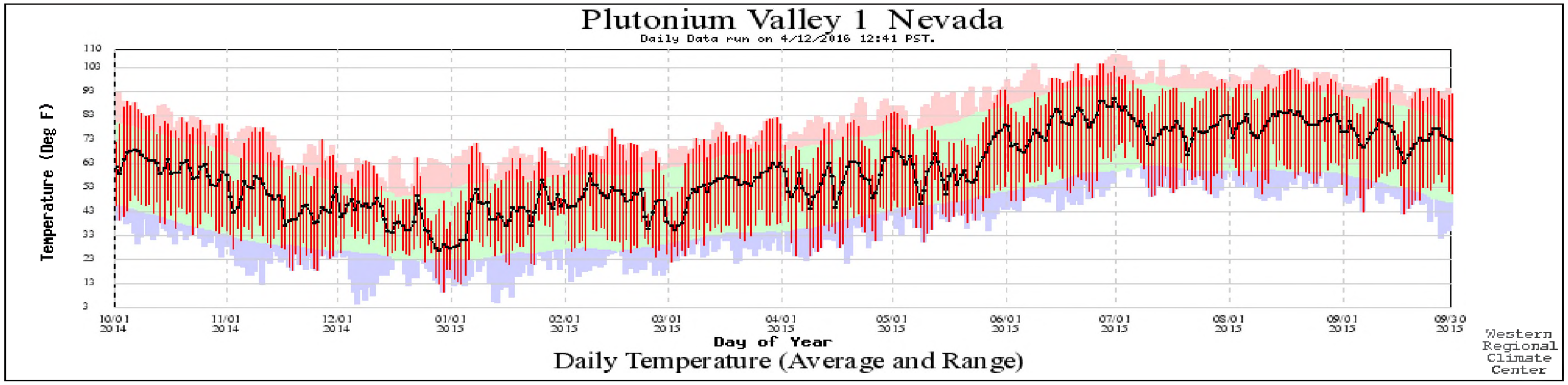

Figure A-1. Daily average (black line) and maximum and minimum (ends of vertical red bar) air temperature from October 1, 2014, to September 30, 2015. Underlying pastel colors represent the period-of-record (2011 to 2015) extremes (red and blue) and averages (green).

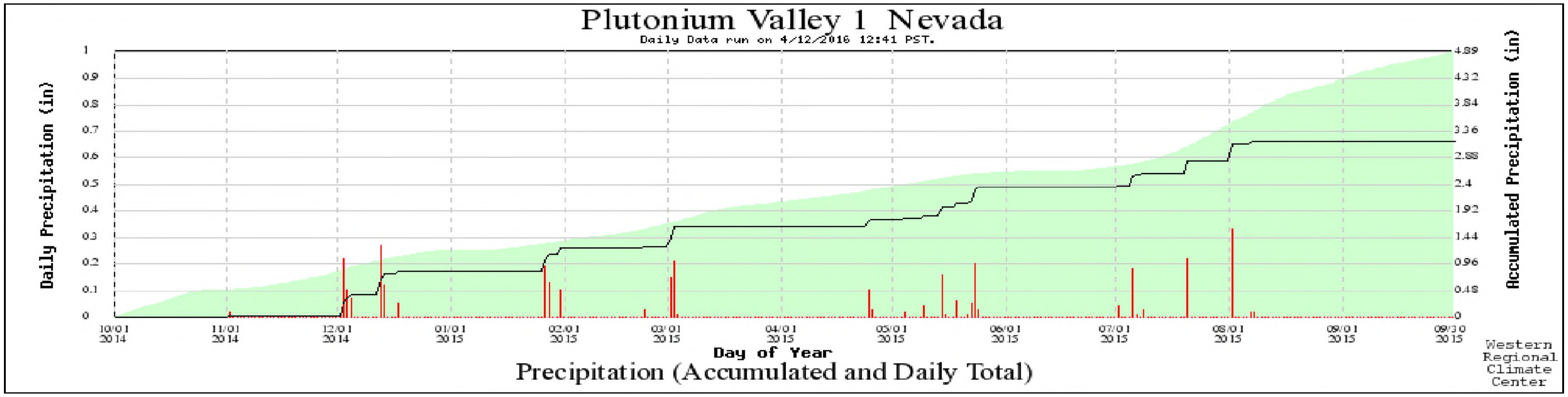

Figure A-2. Daily total (red bars) and accumulated (black line) precipitation data collected at the Plutonium Valley south station from October 1, 2014, to September 30, 2015. Underlying light green shaded area represents the station period-of-record (2011 to 2015) average precipitation accumulation.

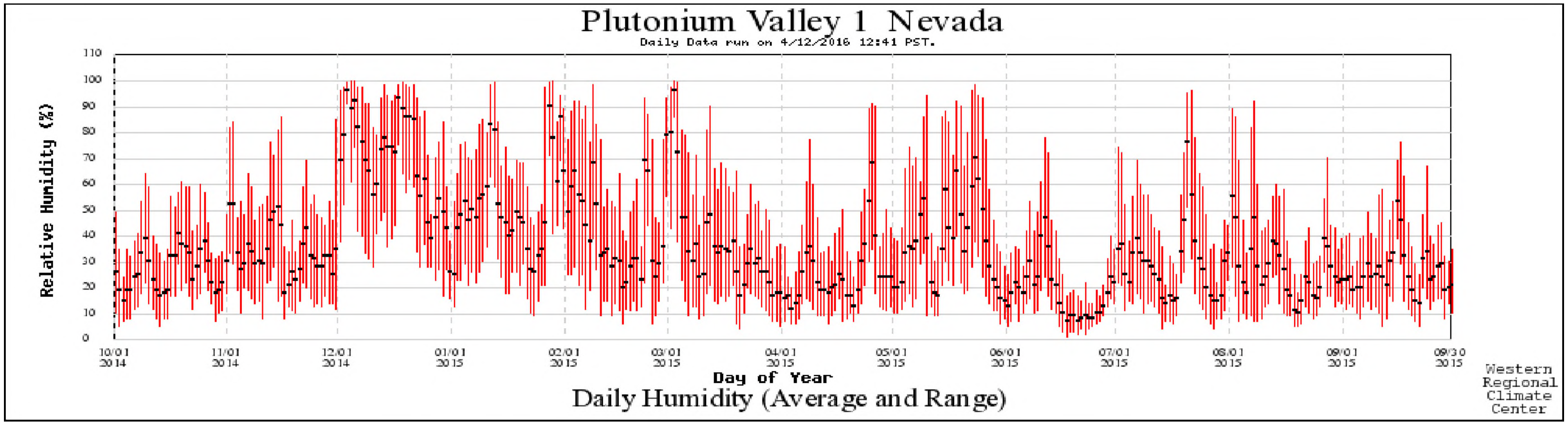

Figure A-3. Daily relative humidity average (black horizontal bars) and maximum and minimum (ends of red vertical bars) recorded at Plutonium Valley south station from October 1, 2014, to September 30, 2015.

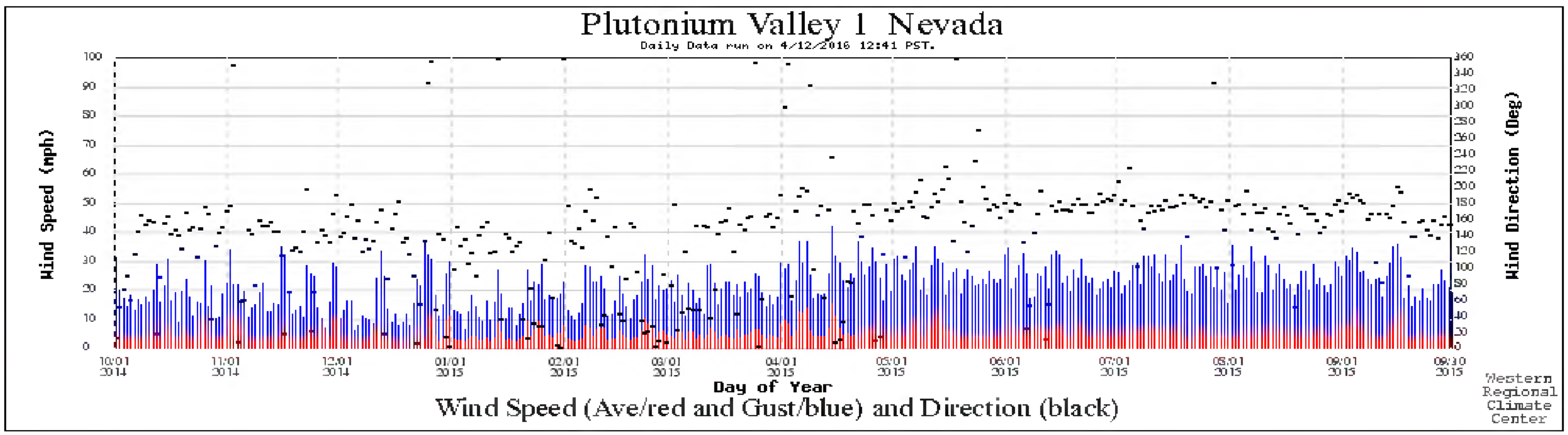

Figure A-4. Wind speed (daily average: red; daily peak gust: blue) and wind direction (black marks) recorded at Plutonium Valley south station from October 1, 2014, to September 30, 2015.

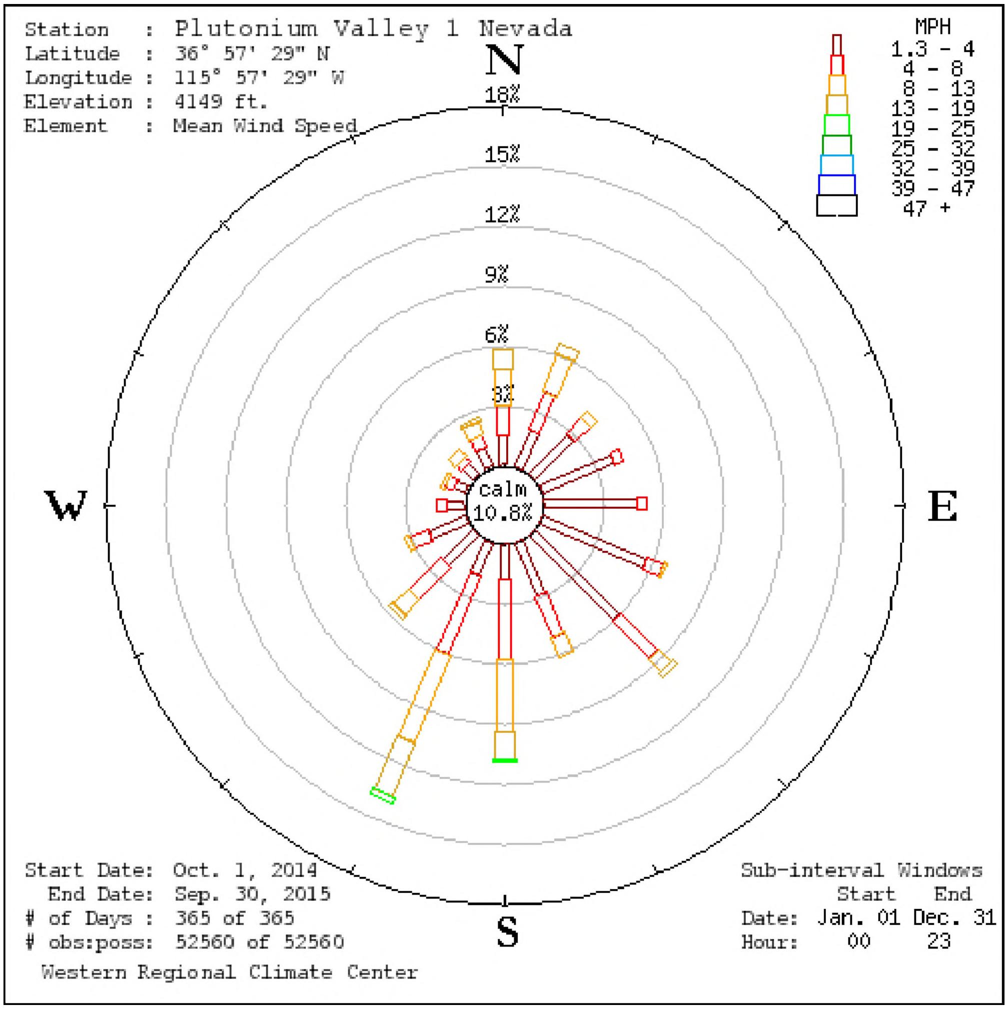

Figure A-5. Wind rose for the period of October 1, 2014, to September 30, 2015, at Plutonium Valley south station.

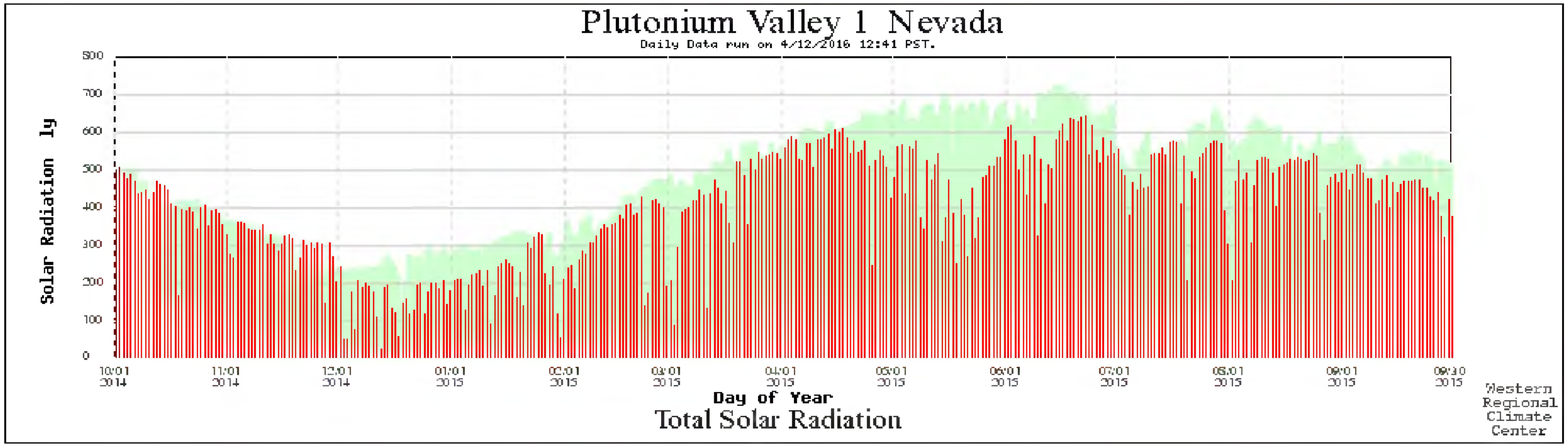

Figure A-6. Daily solar radiation (red bar) recorded at the Plutonium Valley south station from October 1, 2014, to September 30, 2015. Underlying light green shaded area represents the period-of-record (2011 to 2015) maximum daily solar radiation.

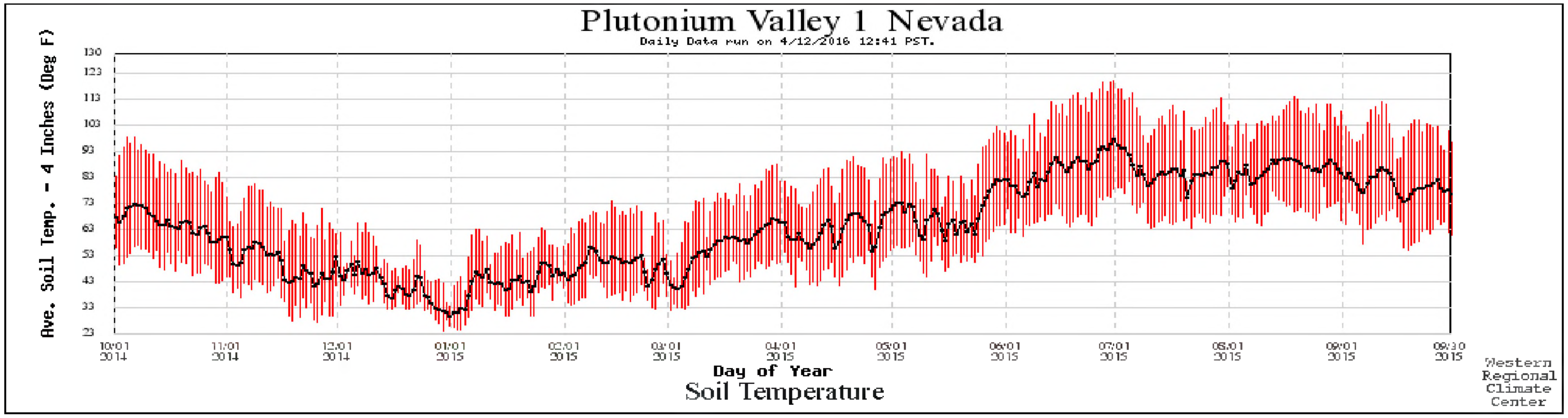

Figure A-7. Daily soil temperature average (black line) and maximum and minimum (ends of red vertical bars) recorded at the Plutonium Valley south station from October 1, 2014, to September 30, 2015.

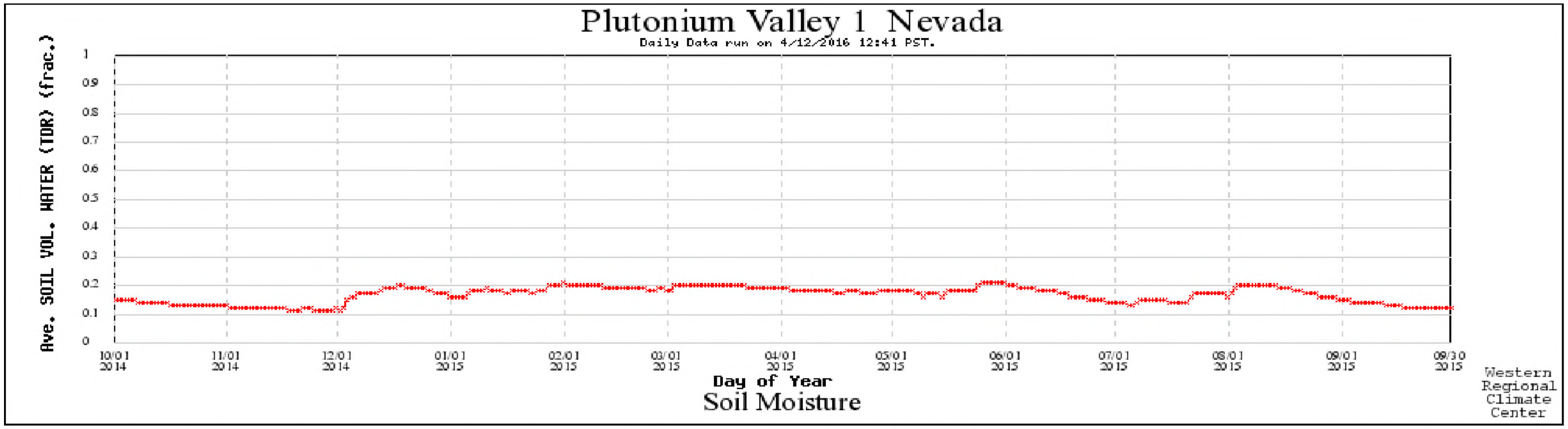

Figure A-8. Daily average soil moisture recorded at the Plutonium Valley south station from October 1, 2014, to September 30, 2015.

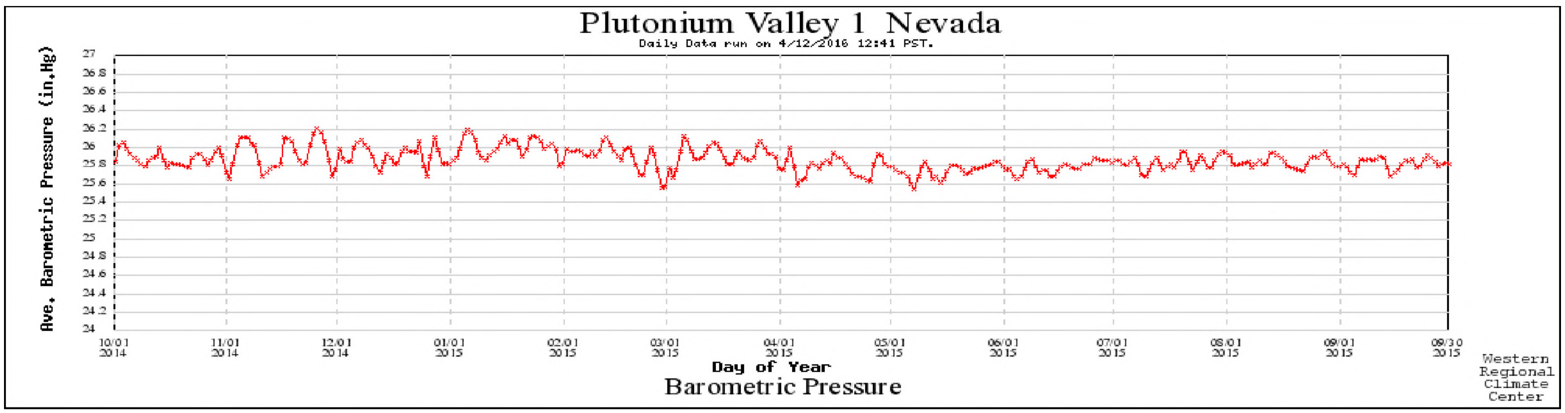

Figure A-9. Daily average barometric pressure recorded at the Plutonium Valley south station from October 1, 2014, to September 30, 2015.

APPENDIX B: FY2015 CHARTS OF METEOROLOGICAL OBSERVATIONS AT PLUTONIUM VALLEY STATION #2

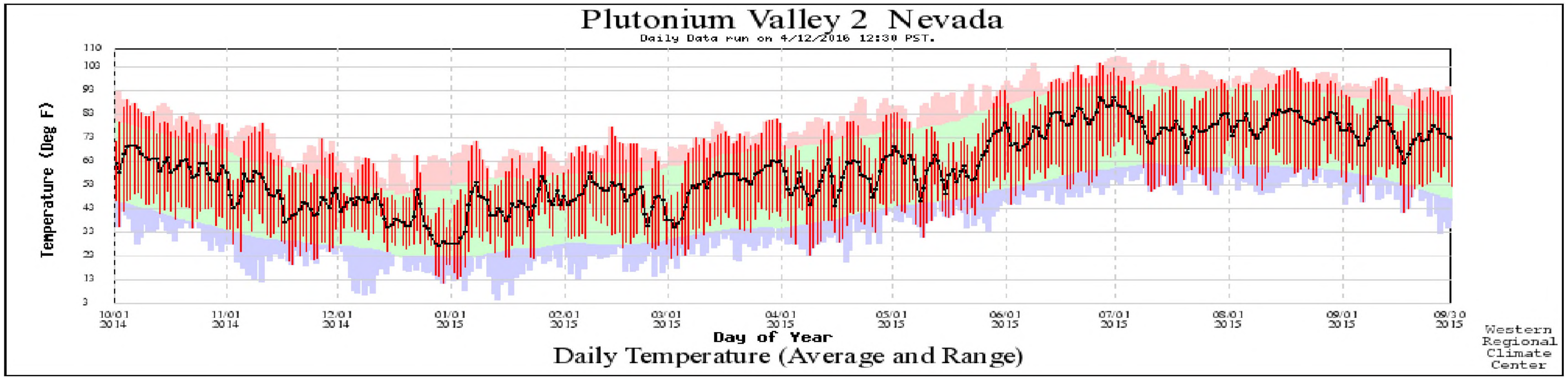

Figure B-1. Daily average (black horizontal bars) and maximum and minimum (ends of red vertical bars) air temperature from October 1, 2014, to September 30, 2015. Underlying pastel colors represent the period-of-record (2011 to 2015) extremes (red and blue) and averages (green).

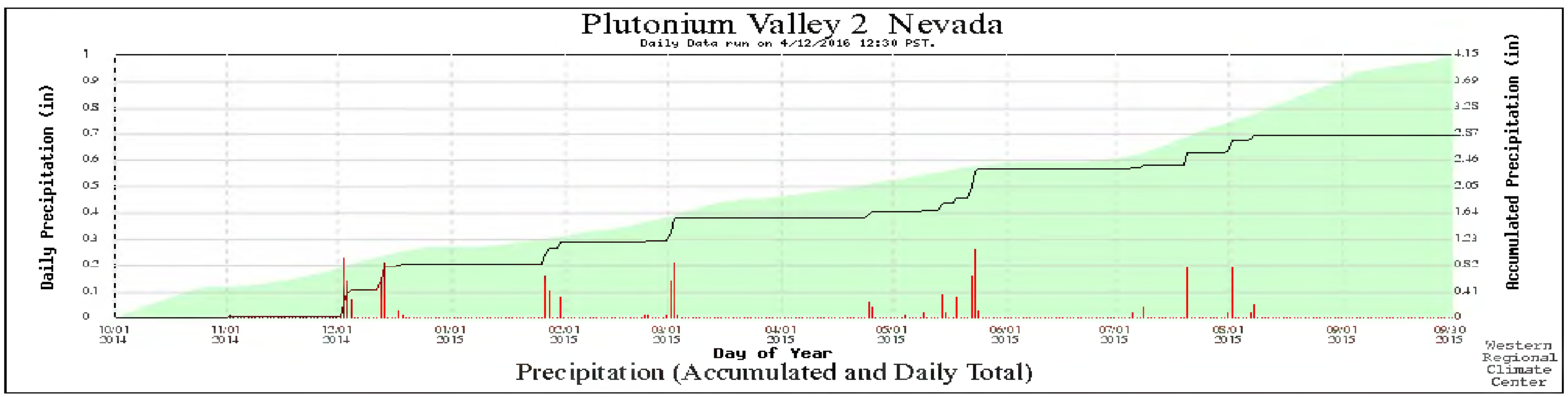

Figure B-2. Daily total (red bars) and accumulated (black line) precipitation data collected at the Plutonium Valley north station from October 1, 2014, to September 30, 2015. Underlying light green shaded area represents the station period-of-record (2011 to 2015) average precipitation accumulation.

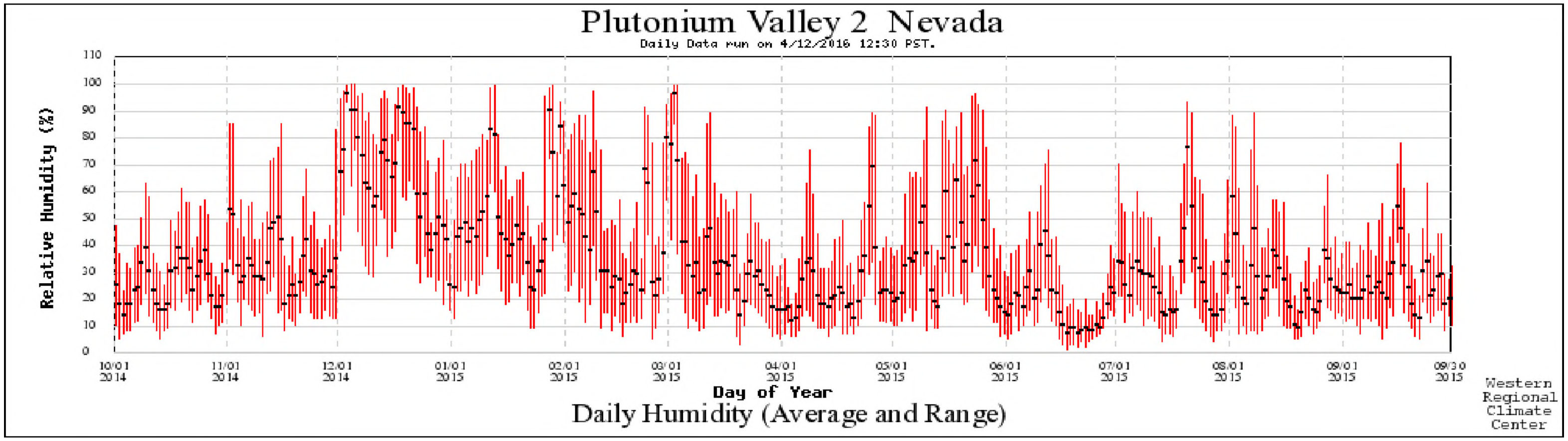

Figure B-3. Daily relative humidity average (black marks) and maximum and minimum (ends of red vertical bars) recorded at Plutonium Valley north station from October 1, 2014, to September 30, 2015.

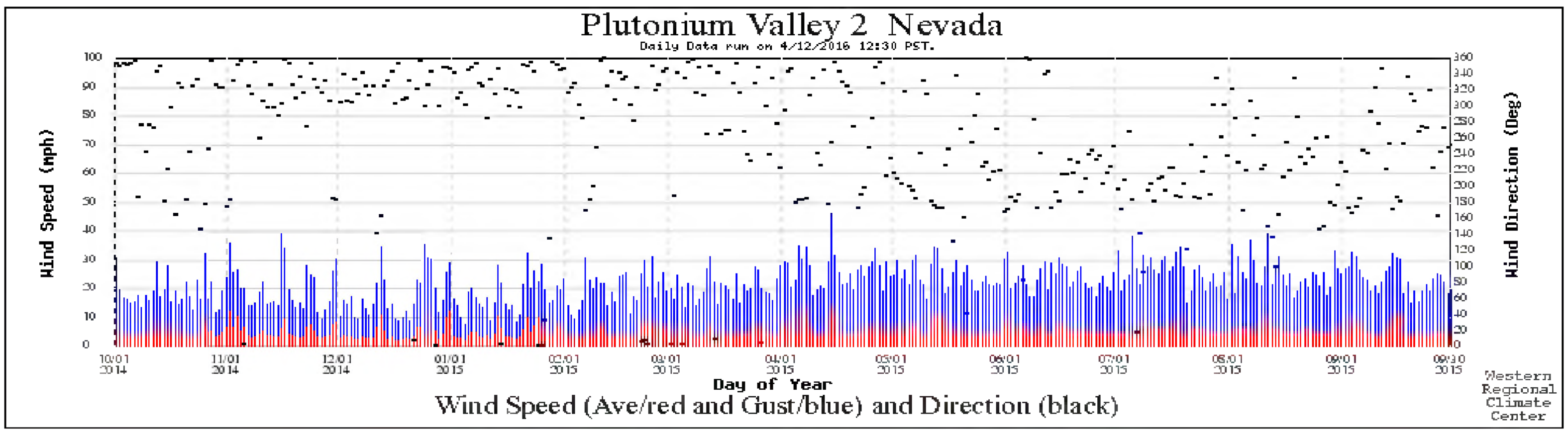

Figure B-4. Wind speed (daily average: red; daily peak gust: blue) and wind direction (black marks) recorded at Plutonium Valley north station from October 1, 2014, to September 30, 2015.

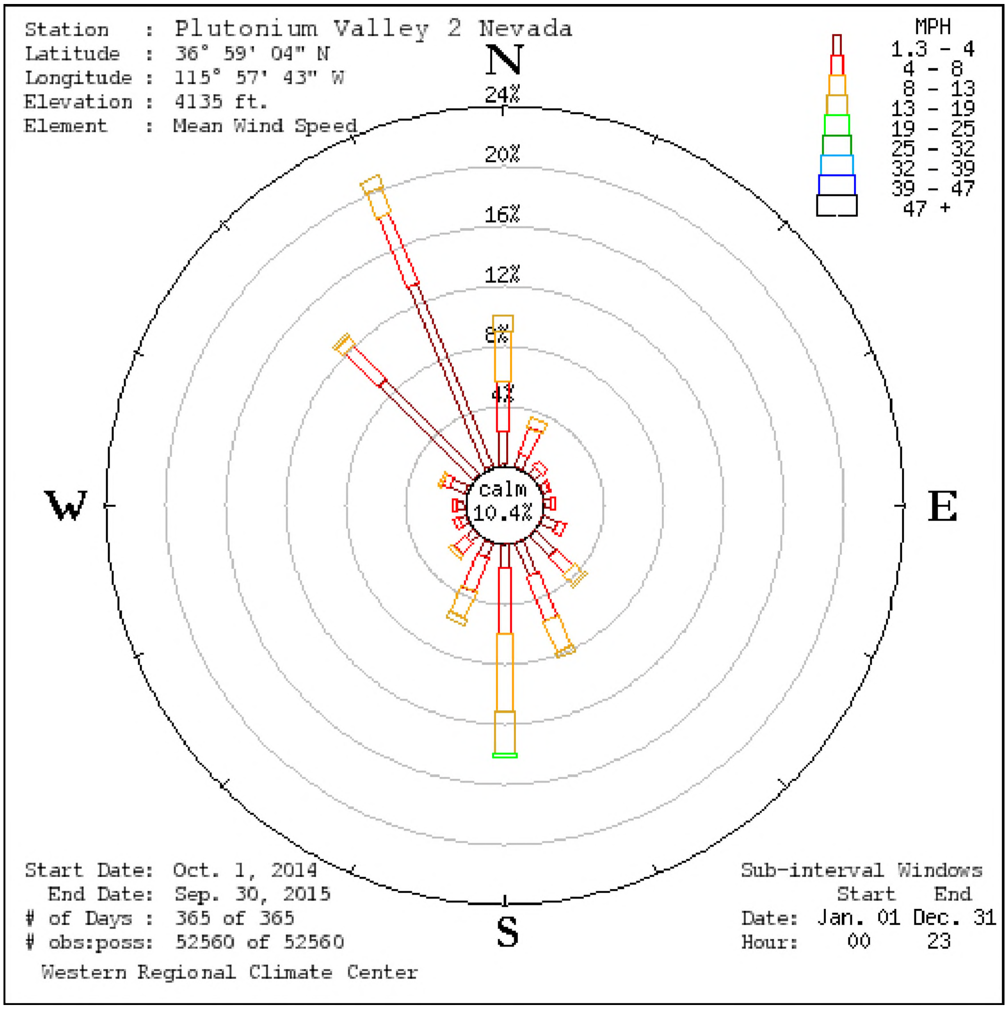

Figure B-5. Wind rose for the period of October 1, 2014, to September 30, 2015, at Plutonium Valley north station.

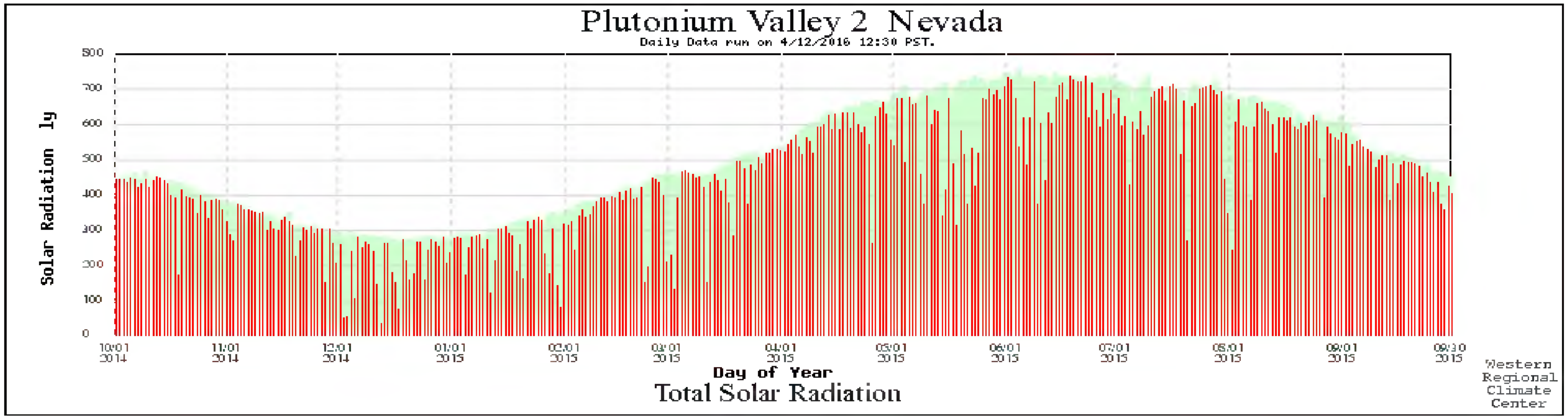

Figure B-6. Daily solar radiation (red vertical bar) recorded at the Plutonium Valley north station from October 1, 2014, to September 30, 2015. Underlying light green shaded area represents the period-of-record (2011 to 2015) maximum daily solar radiation.

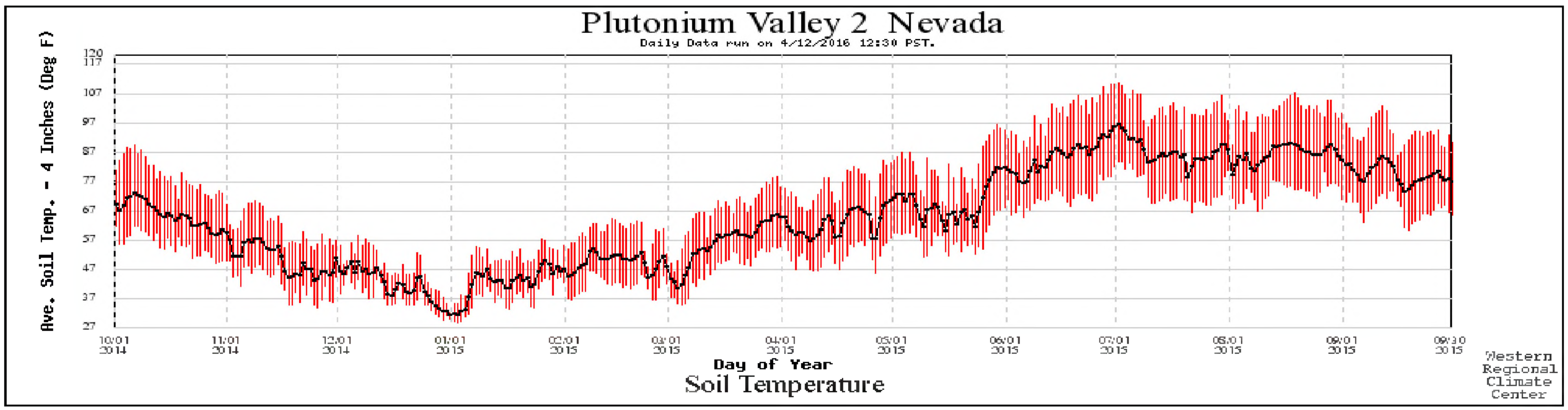

Figure B-7. Daily soil temperature average (black line) and maximum and minimum (ends of red vertical bars) recorded at the Plutonium Valley north station from October 1, 2014, to September 30, 2015.

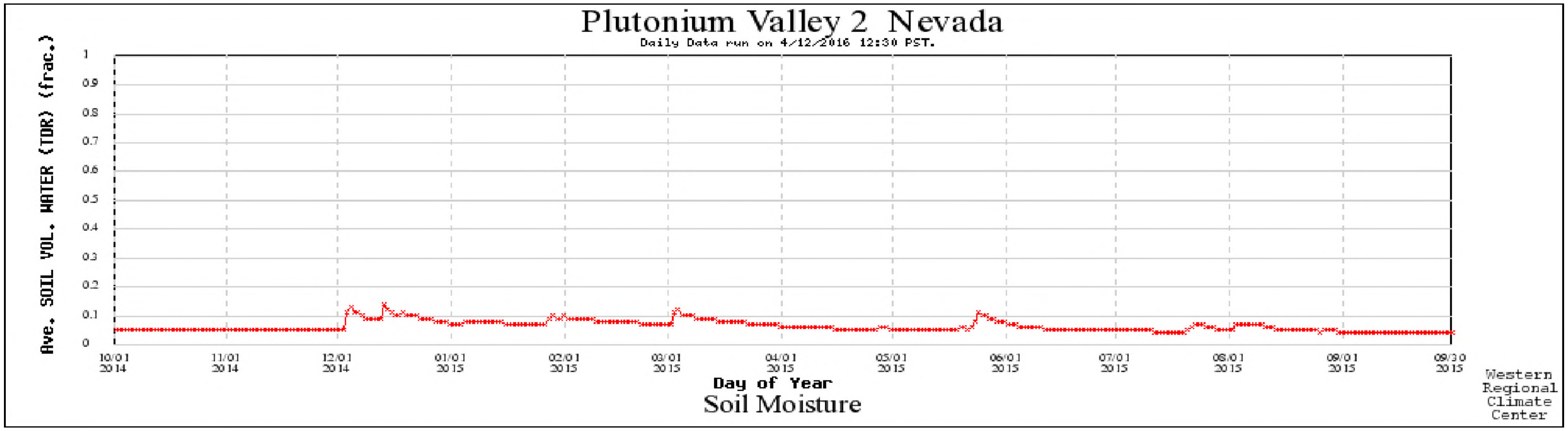

Figure B-8. Daily average soil moisture recorded at the Plutonium Valley north station from October 1, 2014, to September 30, 2015.

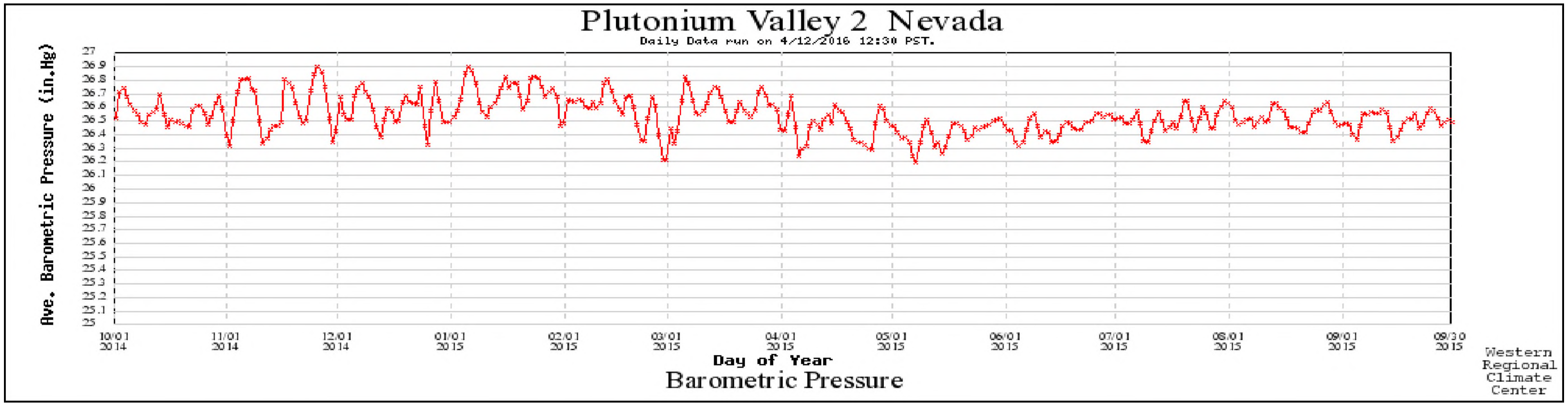

Figure B-9. Daily average barometric pressure recorded at the Plutonium Valley north station from October 1, 2014, to September 30, 2015.

APPENDIX C: ISCO SAMPLER OPERATION FY2015

The ISCO automated sampler is turned on when water is determined to be present in the channel at a sufficient, specified depth. Water presence is determined by a pressure transducer that is calibrated to report the water depth above the transducer, a photoacoustic sensor that is calibrated to report the distance from the sensor to the channel bed or water surface, and a wetness sensor that indicates the presence of water. Because all three water observation systems are subject to error, the ISCO sample pump is turned on only when all three sensors indicate that sufficient water is present for each of six consecutive observations, which are collected at 10-second intervals.

The pressure transducer is programed to report the depth of water above the sensor based on the pressure of water above the transducer. The pressure value is corrected for water temperature using the temperature of the pressure transducer sensor. The pressure transducer is set between cement paving blocks placed in the channel to give the photoacoustic sensor a clean, level reflecting surface. The pressure transducer is approximately two inches (50.8 millimeters) below the top of the paving blocks. Because a two-inch (50.8 millimeters) water depth is required to ensure that the ISCO intake is completely submerged, the transducer output instructs the ISCO to collect a sample only if the water depth above the transducer is greater than four inches (101.6 millimeters). The pressure transducer is subject to output errors because it tends to dry out when the channel is dry and humidity is low and it requires some time to rewet and give accurate values of pressure and water depth.

The photoacoustic sensor produces a sound wave and measures the time between emission and return of the wave from a reflecting surface. The observed time is interpreted to give the distance from the sensor to the reflecting surface. Distance from the sensor to the dry channel reflecting surface at the Plutonium Valley installation was determined to be 5.6 feet (1.71 m) when the sensor was replaced in 2014. The photoacoustic sensor authorizes the ISCO to turn on if the distance to the reflecting surface is less than 5.25 feet (1.6 meters), which is approximately equivalent to a water depth of 4.2 inches (107.95 millimeters). The photoacoustic sensor will also respond to other objects, such as tumbleweeds, and is therefore subject to errors in determining the presence of water in the channel.

The wetness plate is set on edge and embedded into the surficial channel-bed sediments. When dry, the wetness plate has a resistance of 150 ohms. Resistance of the wetness plate decreases as moisture on the plate increases. It is programmed to report the presence of water when the resistance of the plate is < 100 ohms. The moisture increase may result from the presence of water in the channel, condensation from high humidity, or high water content in the channel-bed sediments.

Activation of the ISCO sampler is indicated by a change in the bottle count report. The count goes from zero to one when the ISCO is turned on.

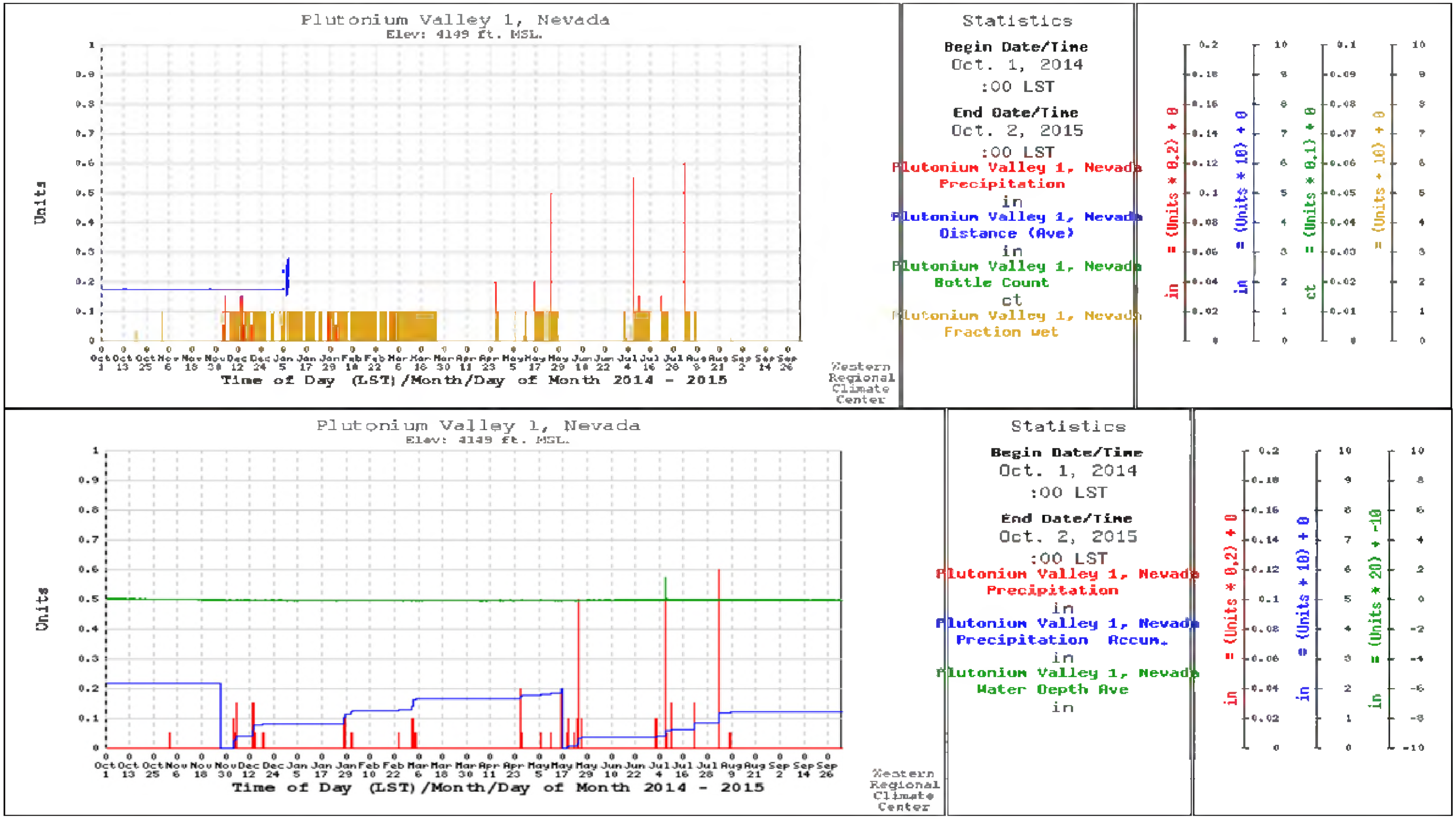

Figure C-1. Depth of water (top) above the pressure transducer and average distance of the reflection surface (bottom) under the photoacoustic sensor and bottle count. No bottle count indicates that the ISCO sample system was not activated during FY2015.

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